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UTILITY PATENT APPLICATION TRANSMITTAL		Attorney Docket No. 98-1984	
(Only for new nonprovisional application under 37 C.F.R. § 1.53(b))		First Inventor or Application Identifier T. S. Zagon	
		Title Novel Nucleic Acid Molecules Encoding Opioid Growth Factor Receptors	
		Express Mail Label No. EK087383601IIS	
APPLICATION ELEMENTS See MPEP chapter 600 concerning utility patent application contents		ADDRESS TO Assistant Commissioner for Patents Box Patent Application Washington DC 20231	
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Docket Number (Optional)

98-1984

Applicant, Patentee, or Identifier: I. S. Zagon

Application or Patent No.: _____

Filed or Issued: November 02, 1999

Title: Novel Nucleic Acid Molecules Encoding Opioid Growth Factor Receptors

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Practitioner's Docket No.: 98-1984

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: I. S. Zagon

Serial No.:

Group No.:

Filed: November 2, 1999

Examiner:

For: NOVEL NUCLEIC ACID MOLECULES ENCODING OPIOID GROWTH FACTOR
RECEPTORS

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**NOVEL NUCLEIC ACID MOLECULES
ENCODING OPIOID GROWTH FACTOR RECEPTORS**

This application claims the priority of U.S.
Provisional Application Serial No. 60/106,879, filed
November 3, 1998.

FIELD OF THE INVENTION

This invention relates to novel nucleic acid
molecules coding for opioid growth factor receptors. The
invention further relates to the use of such nucleic acid
molecules and compositions derived therefrom in
modulating cell growth.

BACKGROUND OF THE INVENTION

Endogenous opioid peptides, first reported by
Hughes and coworkers in 1975 (Hughes et al., *Nature* 258:
577-580, 1975), have been documented to be potent
regulators of growth (Zagon and McLaughlin, *Opioid growth
factor in the developing nervous system*, in: I.S. Zagon
and P.J. McLaughlin (Eds.), *Receptors in the Developing
Nervous System*, vol. 1, *Growth Factors and Hormones*,
Chapman and Hall, London, UK, 1993, pp. 39-62), as well
as neuromodulators (Akil et al., *Ann. Rev. Neurosci.* 7:
223-255, 1984). One native opioid peptide, [Met⁵]-
enkephalin, has been reported to be an inhibitory growth
factor in development, cellular renewal, cancer, wound
healing, and angiogenesis (Isayama, et al., *Brain Res.*
544: 79-85, 1991; McLaughlin, *Amer. J. Physiol.* 271:
R122-129, 1996; Murgo, *J. Natl. Cancer Inst.* 75: 341-344,
1995; Steine-Martin, et al., *Life Sci.* 46: 91-98, 1990; .
Villiger et al., *EMBO J* 11: 135-143, 1992; Zagon and

McLaughlin, 1993, *supra*; Zagon et al., *Amer. J. Physiol*
271: R780-R786, 1996; Zagon et al., *Brain Res.* 798: 254-
260, 1998; Zagon et al., *Brain Res.* 803: 61-68, 1998. In
view of these growth properties, [Met⁵]-enkephalin has
been termed opioid growth factor (OGF) (Zagon and
McLaughlin, 1993, *supra*). OGF is an autocrine produced
and secreted peptide that is not cell, tissue, or organ
specific. While OGF exhibits activity at physiologically
relevant concentrations, it does not elicit physical
dependence, tolerance, and/or withdrawal. OGF displays a
temporal and spatial distribution consistent with
specific growth-related effects and is sensitive to
opioid antagonist displacement. OGF has a direct, rapid,
prolonged, stereospecific, receptor mediated, non-
cytotoxic, and reversible influence on growth both in
tissue culture and in prokaryotic and eukaryotic
organisms. Blockade of the interaction between
endogenous opioids and opioid receptors with compounds
such as naltrexone (NTX) enhances growth (McLaughlin et
al., *Physiol. Behav.* 62: 501-508, 1997; Zagon, et al.,
Science 221: 671-673, 1983; Zagon et al., *Science* 221:
1179-1180, 1983), suggesting that growth related opioid
peptides such as OGF are tonically active. The molecular
nature of OGF is well documented, and this peptide is
encoded by the preproenkephalin gene (Gubler et al.,
Nature 295: 206-209, 1982; Noda et al. *Nature* 295: 202-
206, 1982).

The receptor mediating the action of OGF shares
certain pharmacological characteristics of classical
opioid receptors, including the binding to opioids,
stereospecificity, and naloxone-reversibility (Zagon et
al., *Brain Res.* 551: 28-35, 1991; Zagon et al., *Brain*

Res. 482: 297-305, 1989). Thus, this receptor was originally - and tentatively - termed the zeta (ζ) opioid receptor. However, physiological, pharmacological, receptor binding assays and immunocytochemical
5 localization experiments have revealed the novel nature of this receptor. In particular, the function (growth), tissue distribution (neural and non-neural), subcellular location (nuclear-associated), transient appearance during ontogeny, ligand specificity ([Met⁵]-enkephalin),
10 and competitive inhibition profile differ substantially from what is known about classical opioid receptors.

The present invention provides for the first time the molecular information of the receptor for OGF, in particular, the nucleotide and amino acid sequences of
15 such receptor. Comparison of such sequences with those reported for the opioid receptor family shows no structural homology. In view of the pharmacological, biochemical, physiological and molecular differences, the present invention has termed the receptor tentatively
20 identified as the zeta opioid receptor, the OGF receptor (OGFr).

SUMMARY OF THE INVENTION

One embodiment of the present invention is
25 directed to isolated nucleic acid molecules coding for OGF receptors.

In a preferred embodiment, the present invention provides isolated nucleic acid molecules, SEQ
ID NOs: 1, 4-5, 7, 9, 11 and 13. Degenerate sequences,
30 splice variant sequences, fragments, sequences having deletions, insertions or substitutions, as well as

homologs of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13 are also contemplated by the present invention.

Another embodiment of the present invention is directed to isolated nucleic acid molecules, the complement sequences of which hybridize under stringent conditions to any of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13.

In another embodiment, the present invention is directed to antisense nucleotides of any of the above-described nucleic acid molecules, in particular, antisense nucleic acid molecules of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13. Preferred antisense molecules include SEQ ID NO: 15 and SEQ ID NO: 17, for example.

In still another embodiment, the present invention provides expression vectors in which any of the foregoing nucleic acid molecules or a fragment thereof has been inserted.

In another embodiment, host cells which are transformed with such an expression vector are provided by the present invention.

In still another embodiment, the present invention provides methods of producing recombinant OGF α proteins or peptide fragments thereof by using the nucleic acid molecules of the present invention.

In a further aspect, the present invention provides isolated proteins, the sequences of which are set forth in SEQ ID NOs: 2, 6, 8, 10, 12 and 14. The present invention also contemplates isolated proteins substantially homologous to any of SEQ ID NOs: 2, 6, 8, 10, 12 and 14.

Also embraced by the present invention are functional equivalents or derivatives of any of SEQ ID NO: 2, 6, 8, 10, 12 and 14.

Another embodiment of the present invention is directed to antibodies raised against an OGFr consisting of any one sequence of SEQ ID NOs: 2, 6, 8, 10, 12 and 14, in particular, monoclonal antibodies.

5 In a further aspect of the present invention, pharmaceutical compositions are provided in which one or more of the isolated nucleic acid molecules, antisense molecules, expression vectors, cells, isolated OGFr proteins or functional derivatives and antibodies
10 directed against OGFr proteins of the present invention, are included.

In one embodiment, the present invention provides a method of detecting the expression of an OGFr receptor in a tissue by using a nucleic acid sequence
15 encoding such OGFr or a portion thereof.

In another embodiment, the present invention provides methods for detecting the level of an OGFr in a tissue by using antibodies, particularly, monoclonal antibodies, that specifically recognize the OGFr.

20 In one embodiment, the present invention provides methods of inhibiting growth of cells *in vitro* by administering to such cells, an effective amount of nucleic acid molecules coding for an OGFr or a functional derivative thereof.

25 In another embodiment, the present invention provides methods of promoting growth of cells *in vitro* by administering to such cells, an effective amount of an OGFr antisense molecule.

30 In another embodiment, the present invention provides methods of promoting growth of cells *in vitro* by administering to such cells, an effective amount of an

antibody directed against an OGFr thereby interfering or inhibiting the function of the OGFr.

5 In still another embodiment, the present invention provides methods of treating cancers in a patient by enhancing the function of the OGF ligand-receptor system in the cancerous cells.

10 Cancers which can be treated by the methods of the present invention include, but are not limited to, cancers of neural tissues such as neuroblastoma, prostate cancer, breast cancer, head and neck cancers, gastrointestinal cancers such as pharyngeal, esophageal, stomach, small and large intestine, liver, rectal, colon and pancreatic, biliary tract cancers including gall bladder and bile duct cancers.

15 In a preferred embodiment, the present invention provides methods of treating cancers in a patient by administering to such patient, an effective amount of a nucleic acid molecule coding for an OGFr or a functional derivative thereof. More preferably, such
20 methods of the present invention are used to treat cancers which are characterized by a deficiency of OGF receptors on the cancerous cells, for example, pancreatic cancer. Desired nucleic acid molecules can be administered in conjunction with OGF.

25 In a further embodiment, the present invention provides methods of promoting growth of cells in a subject in need thereof by interfering with the function of the OGF ligand-receptor system.

30 In a preferred embodiment, the present invention provides methods of promoting growth of cells in a subject in need thereof by administering to such subject, an effective amount of an OGFr antisense

molecule or an antibody against OGFr. Such methods can be used in the treatment of wounded tissues, for example.

BRIEF DESCRIPTION OF DRAWINGS

5 **Figure 1** depicts tissue distribution of mRNA detected by the cDNA clone of OGFr. Total RNA was isolated from 6-day cerebellum and brain and from adult cerebellum (25 mg/lane) and separated on a 1.2% agarose gel containing 6% formaldehyde and transferred to a nylon
10 membrane and hybridized with [³²P]-dCTP labeled cDNA clone #14. A single 2.1 kb mRNA was detected in all tissues examined. The Northern was stripped and hybridized with [³²P]-dCTP labeled G3PDH, a constitutively expressed mRNA, to demonstrate equal loading of the RNA samples.

15 **Figure 2** depicts the nucleotide and amino acid sequences of rat OGFr. 5'- and 3'-untranslated regions are included. Repeats are denoted by single and double underlining.

20 **Figure 3** depicts representative saturation isotherm of specific binding of [³H]-[Met⁵]-enkephalin (square) to purified fusion protein translated *in vitro* from the rat OGFr cDNA clone #12. Mean ± SE binding affinity (K_d) for 6 assays was 2.8 ± 1.1 nM and binding capacity (B_{max}) was 10,530 ± 2,237 fmol/mg protein.
25 Binding was significantly reduced with the addition of 1 mM concentrations of the opioid antagonist naltrexone (circle).

30 **Figure 4** depicts the detection of six-day old (lane 1) and adult (lane 2) rat cerebellar nuclear proteins, native GST protein (lane 3), and recombinant GST-14e protein (lane 4) separated by SDS-PAGE and electrotransferred to nitrocellulose. A: Coomassie blue

stained gel of the electrophoresed proteins. B-D:
Western blots stained with polyclonal antibody generated
against a 17-kD OGF binding protein (B), antibody made to
fusion protein 14e (C), or antibody to GST (D). The
5 staining patterns in panels B and C are similar. The
blot in panel D demonstrates the specificity of the
fusion protein antibody. The control antibody to GST
detected GST and GST-fusion proteins, but not native
nuclear homogenate. Arrows indicate the 62, 32, 30 and
10 17/16 kD OGF binding proteins.

Figure 5 depicts distribution of OGF α in
external germinal cells in adjacent midsagittal sections
of 6-day old rat cerebellum (A, B) as detected by an
antibody to the fusion protein 14e (A) or an antibody to
15 the native 17-kD OGF binding protein (B). Internal
granule cells in adult rat cerebellar sections stained
with antibody to the fusion protein (14e) (C) revealed no
immunoreactivity. Arrows = immunoreactivity. Bar = 50
mm.

Figure 6 depicts histogram of cell number in
cultures of IEC-6 rat intestinal epithelial cells treated
for 48 hr with either sterile water (CO), 10^{-6} M NTX, 10^{-6}
20 M 23-mer S-ODN (antisense), or scrambled oligoprobe
(scrambled). Cells (5×10^3) were plated, and compounds
and fresh media were added 24 hr and 48 hr later. After
25 72 hr in culture, cells were trypsinized, stained with
trypan blue, and counted with a hemacytometer. Data of
different sets are significantly different ($p < 0.001$).

Figure 7 depicts representative saturation
30 isotherm and Scatchard plot (inset) of specific binding
of [3 H]-[Met 5]-enkephalin to a nuclear-enriched fraction

of human placenta. A one-site model of binding was noted.

Figure 8A depicts the nucleotide sequence (SEQ ID NO: 5) and the predicted amino acid sequence (SEQ ID NO: 6) of human OGF_r, clone 8; 5'- and 3'-untranslated regions are included.

Figure 8B-8D depicts alternatively spliced forms of OGF_r. Colors indicate regions of identity between splice variants.

8B. Nucleotide splicing.

8C. Peptide structure of clones 1 and 127 compared to clone 8. Clone 1 and clone 127 lack the imperfect repeats.

8D. Comparison of repeats in clones #4, 7, and 8. Differences in amino acids are noted in red (presumably due to polymorphisms in the population), and repeats are designated by alternate underlining. Repeats are numbered 1-5, and arrows indicate positions of apparent alternative splicing.

Figure 8E depicts FISH preparation and a companion ideogram (from the International System for Human Cytogenetic Nomenclature, 1995) showing the localization of OGF_r to chromosome 20q13.3 (arrow).

Figure 9 depicts Northern blot analysis of the receptor for OGF in human fetal (A) and adult (B) tissues, and cancer cells and tissues (C, D); corresponding β -actin level is shown below each blot.

Figure 10 depicts histogram of cell number in cultures of SK-N-AS human neuroblastoma cells treated for 48 hr with either sterile water (CO), 10^{-6} M NTX, 10^{-6} M S-ODN, or scrambled oligonucleotide. Cells (6×10^3) were

plated and compounds and fresh media added 24 hr and 48
hr later. After 72 hr in culture, cells were
trypsinized, stained with trypan blue, and counted with a
hemacytometer. Significantly different from CO at $p < 0.01$
(***).

Figure 11 depicts the comparison of amino acid
similarity between human and rat OGFr. The amino acid
similarity is not consistent throughout the OGFr, being
higher at the N-terminus. Numbers below boxes indicate
amino acid position of the boundaries determined by
inspection.

Figure 12 depicts the dependence of binding of
[^3H]-[Met 5]-enkephalin on the protein concentration of
PANC-1 nuclear homogenates. Increasing concentrations of
protein were incubated with 2 nM radiolabeled [Met 5]-
enkephalin in the presence or absence of 100 nM unlabeled
[Met 5]-enkephalin for 60 min at 4°C at pH 7.4. Values are
means \pm SE for at least 2 experiments performed in
duplicate.

Figure 13 depicts the dependence of binding of
[Met 5]-enkephalin to PANC-1 nuclear homogenates on time
and temperature of incubation. Nuclear protein
homogenates were incubated with 2 nM [^3H]-[Met 5]-
enkephalin in the presence or absence of unlabeled
[Met 5]-enkephalin (for nonspecific binding) at 4°C, 22°C,
or 37°C for varying periods of time. Data are means \pm SE
for at least 3 experiments performed in duplicate.

Figure 14 depicts the dependence of binding of
[^3H]-[Met 5]-enkephalin to PANC-1 nuclear homogenates on pH
of the incubation buffer. Nuclear protein homogenates
were incubated with 2 nM [^3H]-[Met 5]-enkephalin in the
presence or absence of unlabeled [Met 5]-enkephalin (for

nonspecific binding) at 22°C at a variety of pH levels for the buffer. A pH value of 7.4 appeared to be optimal.

Figure 15 depicts the effects of cations (Na⁺, Ca⁺⁺, Mg⁺⁺) and guanylylimidodiphosphate (GppNHp) on binding of [³H]-[Met⁵]-enkephalin to PANC-1 nuclear homogenates. Histograms represent percentage of maximal binding (mean ± SE) obtained using optimal conditions. Significantly different from optimal binding levels at p<0.05 (*) or p<0.01 (**).

Figure 16 depicts representative saturation isotherm of specific binding of [³H]-[Met⁵]-enkephalin to homogenates of PANC-1 nuclear protein. Mean ± SE binding affinity (K_d) and maximal binding capacity (B_{max}) values from 15 assays performed in duplicate. Representative Scatchard plot (inset) of specific binding of radiolabeled [Met⁵]-enkephalin to PANC-1 protein revealed a one-site model of binding.

DETAILED DESCRIPTION OF THE INVENTION

One embodiment of the present invention is directed to isolated nucleic acid molecules. The nucleic acid molecules of the present invention can be of any mammalian origin, including human, pig, dog, monkey, chicken, cow, horse, sheep, murine, rat and the like.

In particular, the present invention provides isolated nucleic acid molecules coding for OGF receptors.

As used herein, an OGF receptor (OGFr) refers to a protein to which the prototypic ligand OGF binds, and through which the growth-related effects of OGF are mediated. OGF is a tonically suppressive autocrine peptide, and its action on growth as an inhibitory agent

is dose-related, reversible, prolonged, independent of serum, and not cytotoxic. The growth-related effects of OGF are associated with cell proliferation, differentiation, and migration, as well as tissue organization. These effects of OGF occur in developing, regeneration, renewing (homeostatsis), wound healing and angiogenesis.

In a preferred embodiment, the present invention provides isolated nucleic acid molecules having SEQ ID NOS: 1, 4-5, 7, 9, 11 and 13.

A cDNA clone having SEQ ID NO: 1 has been isolated from a λ gt11 expression cDNA library constructed from fetal rat brain mRNA. Such cDNA encodes a protein of 580 amino acid (SEQ ID NO: 2).

cDNA clones of SEQ ID NOS: 4-5, 7, 9, 11 and 13 encoding multiple alternatively spliced forms of a human OGF receptor have been obtained by assembling the sequences of 5' and 3' RACE products using human placenta mRNA. The longest assembled clone (SEQ ID NO: 5) encodes a protein of 697 amino acids (SEQ ID NO: 6). SEQ ID NOS: 4-5, 7, 9, 11 and 13 share a portion of the nucleotide sequence at the 5' region, but differ in the 3' region. The polypeptide sequences encoded by these cDNA clones are set forth in SEQ ID NOS: 6, 8, 10, 12 and 14. SEQ ID NO: 5 differs from SEQ ID NO: 4 by having additional 118 nucleotides at the 3' untranslated region.

The present invention also contemplates degenerate sequences of SEQ ID NOS: 1, 4, 5, 7, 9, 11 and 13, i.e., nucleic acid molecules encoding any of the polypeptides of SEQ ID NOS: 2, 6, 8, 10, 12 and 14, which employ alternative codons to those present in SEQ ID NOS: 1, 4-5, 7, 9, 11 and 13.

Fragments of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13 are also provided by the present invention, for example, SEQ ID NO: 3 (a partial rat cDNA clone).

As used herein, "a fragment of a nucleic acid molecule" should be at least about 12, preferably about 15 bp in length. Fragments of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13 can be used as probes to screen cDNA libraries for OGFr genes from other species using, e.g., Southern Blot or PCR. Fragments of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13 can also be inserted in expression vectors to make the encoded peptides.

In another embodiment, the present invention is directed to nucleic acid molecules that are substantially homologous to any of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13.

The phrase "substantially homologous" when referring to nucleotide sequences, denotes the degree of homology of at least 45%, more preferably, at least about 60%, even more preferably, at least about 75%. The degree of homology as used herein is calculated by using the GAP program with a unary comparison matrix, a 3.0 gap penalty, an additional 0.10 penalty for each symbol in each gap, and no penalty for end gaps.

Nucleic acid molecules substantially homologous to any of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13 can be obtained by a variety of well-known techniques. For example, oligonucleotides or DNA fragments can be made from SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13 and employed to screen cDNA libraries for homologous nucleic acid molecules using techniques such as PCR or DNA hybridizations under stringent conditions.

"Stringent conditions" as used herein refer to conditions such as, 18 hours of hybridization at 65°,

followed by four one-hour washes with 2x SSC, 0.1% SDS,
and a final wash with 0.2x SSC, more preferably 0.1x SSC,
and 0.1% SDS for 30 minutes, as well as alternate
conditions which afford the same level of stringency, and
more stringent conditions.

Thus, isolated nucleic acid molecules, the
complement sequences of which hybridize under stringent
conditions to any of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13,
are also included in the present invention.

Nucleic acid molecules that are substantially
homologous to the subject nucleic acid molecules or
hybridize to the complement sequences of the subject
nucleic acid molecules, also include variants of the
subject nucleic acid molecules, such as alternative
spliced forms and degenerate forms.

Given the nucleic acid molecules encoding OGF
receptors, those skilled in the art can readily make
modifications, including substitutions, deletions or
additions of one or more base pairs, to obtain nucleic
acid molecules coding for modified forms of opioid
receptors. For example, those skilled in the art can
identify the domain(s) that are responsible for the
binding of OGF and the domain(s) that interacts with
downstream signaling molecules, and thus can make
modified forms of OGF receptors that either have superior
OGF binding capacities, or can bind OGF but can not
interact with downstream signaling molecules so as to
accomplish the desired OGF-mediated biological function.
Modified OGF receptors can be in the form of
substitutions, deletions (including truncations) or
insertions of one or more amino acids. Depending on the
circumstance, modified forms of OGF receptors can be used

to modulate cell growth, either to stimulate or to inhibit cell growth.

In another embodiment, the present invention is directed to antisense nucleotides of any of the above-described nucleic acid molecules, in particular,
5 antisense nucleic acid molecules of SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13.

In a preferred embodiment, the present invention provides antisense molecules SEQ ID NO: 15 and
10 and SEQ ID NO: 17.

As used herein, the term "antisense nucleotide", "antisense oligonucleotide" or "antisense molecule" refers to an oligonucleotide that hybridizes under physiological conditions to a particular gene or to
15 an mRNA transcript of such gene and, thereby, inhibits the transcription of such gene and/or the translation of such mRNA. The antisense molecules are designed so as to interfere with transcription or translation of a target gene upon hybridization with the target gene or its mRNA.

It is recognized by those skilled in the art that the exact length of the antisense oligonucleotide and its degree of complementarity with its target depend upon the specific target selected. Preferably, an
20 antisense oligonucleotide is constructed so as to bind selectively with the target under physiological
25 conditions, i.e., to hybridize substantially more to the target sequence than to any other sequence in the target cell under physiological conditions.

Based upon SEQ ID NOs: 1, 4-5, 7, 9, 11 and 13,
30 those skilled in the art can generate appropriate antisense molecules for use in accordance with the present invention. In general, such antisense

oligonucleotides should be at least 7, and preferably, at least about 15 consecutive bases which are complementary to the target DNA or mRNA. Most preferably, the antisense oligonucleotides contain a complementary sequence of 20-30 bases. Although oligonucleotides may be designed according to any region of a gene or its mRNA transcript, preferably, the antisense oligonucleotides are complementary to the 5' region or upstream sites such as translation initiation, transcription initiation or promoter sites.

The antisense oligonucleotides of the invention can be composed of "natural" deoxyribonucleotides, ribonucleotides, or any combination thereof, which are covalently linked, as in natural systems, via a phosphodiester internucleoside linkage.

The antisense oligonucleotides of the invention also may include "modified" oligonucleotides. The term "modified oligonucleotide" as used herein refers to an oligonucleotide in which a synthetic linkage other than a natural 5'-3' phosphodiester linkage is present, and/or a modified base or chemical group is present. Synthetic internucleoside linkages include phosphorothioates, alkylphosphonates, phosphorodithioates, phosphate esters, alkylphosphonothioates, phosphoramidates, carbamates, carbonates, phosphate triesters, acetamidates, peptides, and carboxymethyl esters. Modified oligonucleotides can include a 2'-O-alkylated ribose group, sugars such as arabinose instead of ribose, base analogs such as C-5 propyne modified bases (Wagner et al., *Nature Biotechnology* 14:840-844, 1996).

In another embodiment, the present invention provides expression vectors in which any of the foregoing

nucleic acid molecules or a fragment thereof has been inserted for purposes of propagation of such nucleic acid molecule and/or production of the polypeptide encoded thereby.

5 For propagation of a desired nucleic acid molecule, the nucleic acid molecule can be inserted into a vector having a replication origin operable in a desired host, and preferably, a selectable marker, e.g., a marker conferring resistance to an antibiotic. Many of
10 these vectors are available to those skilled in the art, such as pBR322 (New England Biolab), pBluescript (Stratagene) and the like. For purpose of expression, a desired nucleic acid molecule can be placed in an operable linkage to a promoter and inserted into a vector
15 appropriate for directing expression in a desired host. For expression in a eukaryotic cell, viral vectors are preferred, e.g., a retroviral, adenoviral, herpes simplex viral vectors or yeast vectors. For expression in a prokaryotic cell, phage vectors are preferred. For
20 expression in an insect cell, baculovirus-based vectors can be used.

 In still another embodiment, host cells which are transformed with such an expression vector are provided by the present invention. Those skilled in the
25 art are equally familiar with the choice of cell lines and the procedures to transform such cell lines. Examples of the cell lines include, but are not limited to, eukaryotic cells, e.g., COS cells such as COS-7, CHO cells such as CHO-1, NIH 3T3 cells, yeast cells such as
30 strains of *Saccharomyces* and *Pichia pastoris*, insect cells such as *Spodoptera frugiperda*; and prokaryotic

cells, e.g., strains of *E. coli*, strains of *Pseudomonas* such as *Pseudomonas aeruginosa* or strains of *Bacillus*.

In another embodiment, the present invention provides methods of producing recombinant OGFr proteins or peptide fragments thereof by using the nucleic acid molecules of the present invention.

In accordance with such methods, a nucleic acid molecule encoding an OGFr or a peptide fragment thereof is inserted into an expression vector, which is then transformed into a desired host cell. Choices of expression vectors and host cells have been described herein above. Recombinantly expressed proteins can be purified from the transformed cells following routine procedures.

In a further aspect, the present invention provides isolated proteins, the sequences of which are set forth in SEQ ID NOs: 2, 6, 8, 10, 12 and 14.

According to the present invention, SEQ ID NO: 2 sets forth the amino acid composition of rat OGFr, SEQ ID NO: 6, 8, 10, 12 and 14 set forth the amino acid compositions of 5 alternatively spliced human OGFr, with SEQ ID NO: 6 constituting the longest polypeptide (697 aa).

The present invention also contemplates isolated proteins substantially homologous to any of SEQ ID NOs: 2, 6, 8, 10, 12 and 14. Such homologous proteins can be of any mammalian origin which includes human, pig, dog, monkey, chicken, cow, horse, sheep, murine, rat and the like.

By "substantial homologous" is meant the degree of amino acid similarity of at least about 45%, preferably at least about 60%, and more preferably at

least about 75%. As used herein, the degree of similarity is calculated using the BESTFIT Program (Wisconsin GCG release 8) with the following set of parameters: Gap Weight = 5.0, Length Weight = 0.3, Average Match = 1.0, and Average Mismatch = 0.9.

Also embraced in the present invention are functional equivalents or derivatives of any of SEQ ID NO: 2, 6, 8, 10, 12 and 14.

For purpose of the present invention, "a functional derivative of a protein" includes any modified form of such protein which retains one or more of the biological activities of such protein. A typical biological activity of an OGFr is its specific binding to Met⁵-enkephalin, which binding can be reversibly blocked by naltrexone or naloxone. Other biological activities of an OGFr manifest as, e.g., inhibition of cell growth.

The modification of an OGFr can include amino acid deletions, insertions, substitutions or truncations. It is appreciated by those skilled in the art that regions of OGFrS that are well conserved among species may be critical in preserving the biological activities of the OGFrS. Notably in this regard, a prominent feature shared by the isolated proteins of the present invention is the presence of multiple copies of imperfect repeats, as indicated in **Figure 2** and **Figure 8**. In addition, when comparing SEQ ID NO: 2 (rat OGFr) with SEQ ID NO: 6 (human OGFr) (**Figure 11**), a striking similarity is observed in the first 297 amino acids, with 87% being similar and 79% identical. Beyond this point, the number of both similar and identical amino acids drops notably. Thus, a 56% similarity and a 40% identical amino acid profile could be found from amino acids 297 to 464; a

similarity ranging from 43 to 47% , and identical amino acids ranging from 20 to 23% were found thereafter. Therefore, rat OGFr and human OGFr have a great similarity at the N terminus, but dissimilarities at the C terminus.

Another embodiment of the present invention is directed to antibodies raised against an OGFr consisting of any one sequence of SEQ ID NOs: 2, 6, 8, 10, 12 and 14.

The antibodies of the present invention can be generated by using a full-length OGFr protein or a portion thereof as an immunogen. For the purpose of raising antibodies, "a portion of an OGFr protein" refers to a peptide of at least 8 or 9 amino acids. Preferably, the protein or a portion thereof for use as an antigen, is obtained from a recombinant expression system, or chemical synthesis in a standard peptide synthesizer.

Antibodies can be generated by injecting an effective amount of an OGFr protein or a portion thereof into a suitable animal, alone or in combination with an adjuvant. Such animal can include rabbit, chicken, rat, mouse, goat, horse and the like. Both polyclonal antibodies and monoclonal antibodies are contemplated by the present invention. The procedures for making polyclonal and monoclonal antibodies are well known in the art and can be found in, e.g., Harlow, E. and Lane, D., *Antibodies: A Laboratory Manual*, Cold Spring Harbor Press, 1988.

In a further aspect of the present invention, pharmaceutical compositions are provided in which one or more of the isolated nucleic acid molecules, antisense molecules, expression vectors, cells, isolated OGFr

proteins or functional derivatives and antibodies directed against OGFr proteins of the present invention, are included.

5 The pharmaceutical compositions of the present invention can also include a pharmaceutically-acceptable carrier. As used herein, "a pharmaceutically-acceptable carrier" includes any and all solvents, dispersion media, isotonic agents and the like. Except insofar as any
10 conventional media, agent, diluent or carrier is detrimental to the recipient or to the therapeutic effectiveness of the active ingredients contained therein, its use in practicing the methods of the present invention is appropriate. The carrier can be liquid, semi-solid, e.g. pastes, or solid carriers. Examples of
15 carriers include oils, water, saline solutions, alcohol, sugar, gel, lipids, liposomes, resins, porous matrices, binders, fillers, coatings, preservatives and the like, or combinations thereof. The carrier for use in the present methods can also be a controlled release matrix, a material which allows the slow release of substances mixed or admixed therein. Examples of such controlled
20 release matrix material include, but are not limited to, sustained release biodegradable formulations described in U.S. Patent 4,849,141 to Fujioka et al., U.S. Patent 4,774,091 to Yamashira, U.S. Patent 4,703,108 to Silver et al., and Brem et al. (*J. Neurosurg.* 74: 441-446, 1991),
25 all of which are incorporated herein by reference.

The pharmaceutical compositions of the present invention can also include other appropriate active
30 ingredients, such as pentapeptide Met⁵-enkephalin.

In accordance with the present invention, the active ingredients of the present pharmaceutical

compositions can be combined with the carrier in any convenient and practical manner, e.g., by admixture, solution, suspension, emulsification, encapsulation, absorption and the like, and can be made in formulations such as tablets, capsules, powder, syrup, suspensions that are suitable for injections, implantations, inhalations, ingestions or the like. When appropriate, the pharmaceutical compositions of the present invention should be made sterile by well known procedures. For example, solutions can be made sterile by filter sterilization or autoclave. To obtain a sterile powder, sterilized solutions can be vacuum-dried or freeze-dried as necessary.

In a further aspect of the invention, the nucleic acid molecules encoding an OGFr or a portion thereof, as well as the antibodies against an OGFr, are employed to detect the level or the expression of an OGFr in a tissue or organ. Comparison of the level or the expression of an OGFr within healthy and unhealthy tissues, permit detection of an abnormality of the level or the expression of such OGFr.

In one embodiment, the present invention provides a method of detecting the expression of an OGF receptor in a tissue of a subject by using a nucleic acid sequence encoding the OGFr or a portion thereof.

In general, total RNA can be isolated from a tissue sample of the subject. The level of the OGFr mRNA can be analyzed in various assays, such as Northern Blot Analysis or reverse transcriptase-coupled PCR analysis. The nucleotide sequence for use in these assays should be at least about 15 or 16 base pairs in length. The nucleotide reagent of the present invention can be

detectably labeled, for example, with a radioisotope, a fluorescent compound, or a chemiluminescent compound. The teachings for any of the above-described procedures are well-known to those skilled in the art and can be
5 found in, e.g., *Current Protocols in Molecular Cloning* (Ausubel et al., eds., John Wiley & Sons, New York).

In another embodiment, the present invention provides methods for detecting the level of an OGFr in a tissue by using antibodies, particularly, monoclonal
10 antibodies, that specifically recognize the OGFr.

According to the present invention, the level of an OGFr in a tissue can be determined using an antibody and a variety of *in vitro* assays. Generally, a tissue sample can be taken from the subject, and
15 depending on the assay used, the sample may need to be pretreated. For example, cells can be homogenized, proteins can be extracted from the homogenized cells.

The *in vitro* assays which can be employed herein include, e.g., immunoassays that are based on
20 antigen capture, antibody capture (e.g., ELISA, Western Blot, etc), or two antibody sandwich assay (either forward or reverse mode). Multiple teachings are available for those skilled in the art. See, e.g., Harlow, E. and Lane, D., *Antibodies: A Laboratory Manual*,
25 Cold Spring Harbor Press, 1988.

The antibodies or the proteins isolated from the sample can be utilized in liquid phase or bound to a solid phase carrier. Examples of well-known carriers include glass, polystyrene, polypropylene, polyethylene,
30 dextran, nylon, amylases, natural and modified cellulose, polyacrylamides, agaroses and magnetite. In addition, the antibodies or the proteins isolated from the tissue

sample can be detectably labeled in various ways for a quantitative determination. Examples of detectable labels include secondary antibodies, enzymes such as horseradish peroxidase, β -galactosidase or alkaline phosphatase, fluorophores or radioisotope.

In accordance with the present invention, antibodies can also be used *in vivo* for detecting the level of an OGFr in a subject. Monoclonal antibodies are preferred for *in vivo* detection.

In using a monoclonal antibody for *in vivo* detection, the monoclonal antibody is detectably labeled, e.g., with a radioisotope. The skilled artisan can choose a radioisotope according to the type of detection instrument that is available. The chosen radioisotope should have a type of decay which is detectable for a given type of instrument. Preferably, the chosen radioisotope has a half life that is long enough for detection at the time of maximum uptake by the subject, but short enough to minimize deleterious radiation to the subject. A radioisotope suitable for *in vivo* imaging methods of the present invention does not have a particle emission, but produces a large number of photons in the 140-250 keV range which may be readily detected by conventional gamma cameras.

According to the present invention, radioisotopes may be coupled to immunoglobulin by using an intermediate functional group, particularly for binding metallic ion-type of radioisotopes to immunoglobulins. Appropriate intermediate functional groups include the bifunctional chelating agents such as diethylenetriaminepentaacetic acid (DTPA) and ethylenediaminetetraacetic acid (EDTA) and similar

molecules. Typical examples of metallic ions which can be bound to the monoclonal antibodies of the invention are ^{111}In , ^{97}Ru , ^{67}Ga , ^{68}Ga , ^{72}As , ^{89}Zr , and ^{201}Tl .

5 A monoclonal antibody suitable for use in the present methods can also be labeled with a paramagnetic isotope for purposes of *in vivo* diagnosis, as in magnetic resonance imaging (MRI) or electron spin resonance (ESR). In general, any conventional method for visualizing diagnostic imaging can be utilized. Usually gamma and
10 positron emitting radioisotopes are used for camera imaging and paramagnetic isotopes for MRI. Elements which are particularly useful in such techniques include ^{157}Gd , ^{55}Mn , ^{162}Dy , ^{52}Cr , and ^{56}Fe .

15 In accordance with the present invention, a labeled monoclonal antibody can be administered in any appropriate manner, such as via an oral, ophthalmic, nasal, transdermal, parenteral (e.g., intravenous, intraperitoneal, intradermal, subcutaneous or intramuscular), intratumor, intraembryonic, or intrafetal
20 route, to the subject of interest in a quantity that is sufficient to enable a specific detection of the OGFr, and that allows rapid clearance of the reagent from the subject in order to give the best target-to-background signal ratio. The dosage of detectably labeled
25 monoclonal antibody can vary depending on such factors as age, gender, and severity of the disorder of the subject, or the subject's response to a therapeutic regimen. Those skilled in the art can determine the appropriate dose of a monoclonal antibody reagent using conventional
30 techniques. As a general rule, the dosage of a monoclonal antibody can fall in the range of about 0.001 mg/m² to about 500 mg/m², preferably 0.1 mg/m² to about

200 mg/m², most preferably about 0.1 mg/m² to about 10 mg/m². *In vivo* imaging techniques are described in U.S. Patent No. 4,036,945 and No. 4,311,688, the disclosures of which are incorporated herein by reference.

5 In a further aspect of the present invention, the nucleic acid molecules encoding an OGF_r or functional derivatives thereof or modified forms thereof, the antisense molecules and antibodies directed against an OGF, are employed to modulate cell growth.

10 An OGF receptor protein acts together with its native ligand, opioid peptide [Met⁵]-enkephalin (or OGF), to inhibit cell growth. According to the present invention, such ligand-receptor signaling system can be manipulated to achieve desired effects under various
15 physiological circumstances. For example, in cases of cancer, it is desirable to enhance or potentiate the activity of the OGF ligand-receptor signaling system in cancerous cells thereby inhibiting the growth of the cancerous cells. On the other hand, in cases of
20 cellular renewal or regeneration, wound healing or angiogenesis, for example, it maybe desirable to inhibit or reduce the activity of the OGF ligand-receptor signaling system in cells of the desired tissues, thereby enhancing or accelerating the growth of such cells.
25 Thus, the term "modulating" as used herein refers to regulating and manipulating to enhance or reduce the activity of the OGF ligand-receptor signaling system.

In one embodiment, the present invention provides methods of inhibiting growth of cells *in vitro*
30 in need of such inhibition by introducing to such cells *in vitro*, an effective amount of nucleic acid molecules coding for an OGF_r or a functional derivative thereof.

The nucleic acid molecules can be introduced to such cells by well-known procedures, e.g., transfection. Such nucleic acid molecules can be introduced to the cells in conjunction with Met⁵-enkephalin.

5 In another embodiment, the present invention provides methods of promoting growth of cells *in vitro* in need of such promotion by introducing to such cells, an effective amount of an OGFr antisense molecule. The antisense molecules can be introduced to the cells by, 10 e.g., simply adding such antisense molecules to the culture media of the cells.

In another embodiment, the present invention provides methods of promoting growth of cells *in vitro* in need of such promotion by introducing to such cells, an 15 effective amount of an antibody directed against an OGFr thereby interfering or inhibiting the function of the OGFr. The antibodies can be introduced to the cells by, e.g., simply adding such antibody to the culture media of the cells.

20 In still another embodiment, the present invention provides methods of treating cancers in a patient by enhancing the function of the OGF ligand-receptor system in the cancerous cells.

In a preferred embodiment, the function of the 25 OGF ligand-receptor system in the cancerous cells can be enhanced by providing the cancerous cells additional nucleic acid molecules encoding OGF receptors.

30 Thus, the present invention provides methods of treating cancers in a patient by administering to such patient, an effective amount of nucleic acid molecules coding for an OGFr or a functional derivative thereof.

For the purposes of the present invention, the term "treating" means preventing the onset of cancer, inhibiting the growth of existing cancer, preventing the recurrence of cancer, or arresting cancer completely.

5 Cancers which can be treated by the methods of the present invention include, but are not limited to, cancers of neural tissues such as neuroblastoma, prostate cancer, breast cancer, head and neck cancers, gastrointestinal cancers such as pharyngeal, esophageal,
10 stomach, small and large intestine, liver, rectal, colon and pancreatic, biliary tract cancers including gall bladder and bile duct cancers.

 More preferably, the methods of the present invention are used to treat cancers which are
15 characterized by a deficiency of OGF receptors on the cancerous cells. According to the present invention, an example of such cancer is pancreatic cancer.

 A deficiency of OGF receptors can be due to insufficient expression of the receptors or expression of non-functional receptors, as compared with controls,
20 e.g., adjacent normal cells from the same individual or cells from pooled normal individuals.

 A variety of assays can be used to determine whether there is a deficiency of OGF receptors in subject
25 cells. Such assays include those described herein above for detecting the level or the expression of OGF receptors, e.g., Northern Blot or RT-PCR using nucleic acid molecules, and immunoassays using antibodies. Other assays include binding assays which determine the Met⁵-
30 enkephalin binding capacity of subject cells or protein extracted therefrom. Examples of such binding assays are provided hereinafter (Example 6).

Preferably, a nucleotide sequence encoding an
 OGF or a functional derivative thereof for use in
 treating cancers is provided in an expression vector,
 e.g., a typical gene therapy vector. Preferred gene
 5 therapy vectors include retroviral, adenoviral, herpes
 simplex viral, adeno-associated viral and vaccinia
 vectors. Examples of retroviral vectors include, but are
 not limited to, Moloney murine leukemia virus (MoMuLV),
 Harvey murine sarcoma virus (HaMuSV), murine mammary
 10 tumor virus (MuMTV), and Rous Sarcoma Virus (RSV)-derived
 recombinant vectors. More preferably, a non-human
 primate retroviral vector is employed, such as the gibbon
 ape leukemia virus (GaLV), thereby providing a broader
 host range than murine vectors, for example. Gene
 15 therapy vectors can be made tissue specific by, for
 example, linking the nucleotide sequence to a tissue-
 specific promoter. Multiple teachings of gene therapy
 are available for those skilled in the art, e.g., W.F.
 Anderson (1984) "Prospects for Human Gene Therapy"
 20 *Science* 226: 401-409; S.H. Hughes (1988) "Introduction"
Current Communications in Molecular Biology 71: 1-12; N.
 Muzyczka and S. McLaughlin (1988) "Use of Adeno-
 associated Virus as a Mammalian Transduction Vector"
Communications in Molecular Biology 70: 39-44; T.
 25 Friedman (1989) "Progress Toward Human Gene Therapy"
Science 244: 1275-1281 and W.F. Anderson (1992) "Human
 Gene Therapy" *Science* 256: 608-613.

The amount of a nucleic acid molecule to be
 therapeutically effective can be determined according to
 30 the age and the condition of the subject.

Desired nucleic acid molecules can be
 administered in conjunction with OGF. Other appropriate

materials, such as pharmaceutical carriers, can be administered together with the nucleic acid molecules as well. Any of the foregoing described pharmaceutically acceptable carriers can be used, and can be admixed with the nucleic acid molecules in the manner described hereinabove.

The administration of the desired nucleic acid molecules, either alone or with other appropriate material, may be carried out in any convenient manner, including by aerosol inhalation, injection, ingestion, transfusion, implantation or transplantation. Preferably, the administration is carried out by injection, including subcutaneous, intradermal, intramuscular, transdermal, intraperitoneal (i.p.), intra-arterial (i.a.), intravenous (i.v.) injection, or direct injection into the tumor. Multiple administrations may be required, which can be determined by a physician.

In a further embodiment, the present invention provides methods of promoting growth of cells in a subject in need thereof by interfering with the function of the OGF ligand-receptor system.

According to the present invention, the function of the OGF ligand-receptor system can be inhibited by using antisense molecules which interfere with the expression of OGF receptors, or by using antibodies against OGF receptors which interfere, via steric hindrance, e.g., with the function of OGF receptors.

Accordingly, In a preferred embodiment, the present invention provides methods of promoting growth of cells in a subject in need thereof by administering to

such subject, an effective amount of an OGFr antisense molecule or an antibody against OGFr.

Such methods of the present invention can be used to assist in the healing of wounded tissues or organs, including but not limited to the skin, the cornea, liver, uterus, nerves, subcutaneous tissues, mucosal tissues, intestinal tissues, and fetal tissues.

Antisense molecules for use in the methods of the present invention can be placed on expression vectors, such as gene therapy vectors described hereinabove.

The amount of an antisense molecule or an antibody to be therapeutically effective can be determined according to the age and the condition of the subject.

Both antisense molecules and antibodies can be administered alone or in combination with one or more pharmaceutically-acceptable carriers. Such carriers have been described hereinabove. Antisense molecules or antibodies can be admixed with one or more carriers in manners described hereinabove, and then administered via any of the foregoing routes.

This invention is further illustrated by the following examples, which are not to be construed in any way as imposing limitations upon the scope thereof. The terms and expressions which have been employed in the present disclosure are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof. It is to be understood that various modifications are possible within the scope of the

invention. All the publications mentioned in the present disclosure are incorporated herein by reference.

Example 1

Isolation of a cDNA Clone Encoding a Rat OGF Binding Protein

5

An antibody against the rat OGF binding protein (BO461) was produced according to published procedures (Zagon et al., *Brain Res.* 630: 295-302, 1993). In brief, 2-dimensional gels of the nuclear fraction (P1) from a 6-day old rat cerebellum were transferred to
10 nitrocellulose, and ligand blotting with [¹²⁵I]-[Met⁵]-enkephalin was performed to identify an OGF binding protein (Zagon et al., *Brain Res.* 482: 297-305, 1989). The protein was electroeluted and injected into New
15 Zealand white rabbits to generate polyclonal antibodies. Serum was collected and purified using ammonium sulfate precipitation and DEAE Affi-blue gel filtration.

One million plaques from a λgt11 expression cDNA library (oligo-dT primed, original complexity of 1.6 x 10⁶ pfu with insert sizes ranging from 0.6 to 4.0 kb),
20 constructed from 18-day old fetal rat brain mRNA (Clontech, Palo Alto, CA), were screened using the polyclonal antibody that recognized the OGF binding protein. Immunoreactive plaques were identified by
25 reaction with horseradish peroxidase or [¹²⁵I]-protein A. Thirty-two plaques reacted positively to the BO461 antiserum, of which four were purified and subjected to restriction digestion. One of these plaques, designated clone #14 (SEQ ID NO: 3), was characterized further.

30 The 1000 bp cDNA insert from clone #14 was labeled with [³²P]dCTP and used to probe Northern blots of total RNA isolated from 6-day old and adult rat cerebellum. Northern blot analysis was performed

according to McLaughlin and Allar (*Mol. Brain Res.* 60:
160-167, 1998). In brief, RNA was isolated from 6-day
old and adult rat tissues. Membranes were hybridized at
42°C for 16-18 hr in fresh prehybridization buffer
containing 10⁶ cpm/ml of random prime labeled clone #14
cDNA. Filters were subjected to final washes at 60°C
with 0.1 X SSC containing 0.1% SDS for 30 min, wrapped in
plastic while wet, and exposed to autoradiography film
with intensifying screens for 2-4 days at -70°C. To
control for differences in the amount of RNA loaded, as
well as the integrity of RNA, blots were stripped and
probed with [³²P]-labeled cDNA for G3PDH. As shown in
Figure 1, the cDNA probe detected a species of rat mRNA
that was 2.1 kb, expressed abundantly in 6-day old
cerebellum and brain, but at low levels (3-fold less than
at 6-days) in adult cerebellum.

Since the #14 clone was not full length,
labeled #14 cDNA was used as a hybridization probe to
screen the λ gt11 fetal rat brain library for full-length
clones. Thirteen positive clones were identified and
purified from the library by colony hybridization.
Digestion of the purified clones with *EcoR*I released a
full size insert of 2.1 kb from clone #12. The #14 and
the #12 cDNAs were sequenced in both directions. **Figure**
2 shows the nucleotide sequence (SEQ ID NO: 1), and the
deduced amino acid sequence (SEQ ID NO: 2), of the full
length cDNA, #12; 5' and 3' untranslated regions have
been included. The open reading frame was found to
encode a protein of 580 amino acids, with 8 imperfect
repeat units of 9 amino acids at positions 467 to 538.
The molecular weight as calculated from the sequence is

58 kD. Search of the sequences in GenBank revealed no homology to this cDNA.

CCDC100

Example 2
Characterizing the OGF Receptor

Binding Assays

Inserts from clone #14 encoding the C-terminal 197 amino acids of rat OGFr, and from clone #12 encoding all 580 amino acids of rat OGFr, were ligated into the pGEX-3X expression vector (Promega, Madison, WI) to generate glutathione-S-transferase (GST) fusion proteins, referred to herein as 14-GST and 12-GST, respectively. When expressed in XL1-Blue strain bacteria (Stratagene, La Jolla, CA), and induced with isopropyl b-o-thiogalactopyranoside for 3 hr, these plasmids produced GST-OGF-binding fusion proteins which were then purified from crude bacterial extracts using glutathione affinity chromatography and 1-dimensional PAGE gel electrophoresis.

These fusion proteins were used in binding assays with [³H]-[Met⁵]-enkephalin (Zagon et al., *Brain Res.* 551: 28-35, 1991; Zagon et al., *Brain Res.* 605: 50-56, 1993). Fusion proteins (80-120 ng/tube) were incubated for 30 min with shaking at 22°C. Non-specific binding was measured in the presence of unlabeled [Met⁵]-enkephalin. In some assays, NTX (10⁻³ M) was added to the reaction mixture to monitor opioid antagonist blockade of binding. Binding was terminated by filtering homogenates through Whatman GF/B filters. Saturation isotherms were plotted using GraphPad Prism software (GraphPad Software Inc., San Diego, CA).

Specific competition of 12-GST fusion protein was determined in the presence of a range (10⁻¹⁰ to 10⁻³ M)

of ligands including [D-Ala²,MePhe⁴,Glyol⁵]-enkephalin (DAMGO), [D-Pen^{2,5}]-enkephalin (DPDPE), dynorphin A1-8, U69,583, and morphine sulfate (**Figure 3**). Specific and saturable binding was observed, with a mean binding affinity (K_d) of 2.8 ± 1.1 nM and binding capacity (B_{max}) of $10,530 \pm 2,237$ fmol/mg protein. Addition of naltrexone to the preparations significantly reduced specific and saturable binding, with reductions in B_{max} of 83% noted (**Figure 3**). Representative Scatchard plot of specific binding of radiolabeled [Met⁵]-enkephalin revealed a one-site model of binding.

Using a variety of ligands that recognized classical opioid receptors, no competitive binding ($>10^{-3}$ M) for radiolabeled [Met⁵]-enkephalin by DAMGO or morphine sulfate (μ receptor), DPDPE (δ receptor), dynorphin A1-8 and U69,583 (κ receptor) was observed.

Western Blotting

Antibodies against the recombinant fusion proteins were generated by inoculating New Zealand white rabbits with 14-GST or with 12-GST fusion proteins suspended in Freund's adjuvant. The GST was not cleaved from the proteins prior to inoculating the rabbits, allowing the GST to function as a carrier protein. Rabbits were injected every 4 weeks for 2 months, tested for their titer, and exsanguinated 4 days after the final injection.

Nuclear preparations of 6-day and adult rat cerebellum, as well as GST and 14-GST fusion proteins, were isolated by 12.5% SDS PAGE, and electrotransferred to nitrocellulose. Western blotting performed with primary antibodies to either the 14-GST fusion protein

(Zagon et al., *Brain Res.* 630: 295-302, 1993), native OGF binding protein, or GST; [¹²⁵I]-protein A was used for antibody detection.

Antibodies to the recombinant fusion protein derived from clone #14 (14-GST) were titrated and 1:1000 dilutions detected 10 ng of fusion protein. When reacted with nuclear preparations of 6-day old cerebellum on a 1-dimensional Western blot, anti-14-GST recognized 5 polypeptides: 62, 32, 30, 17, and 16 kD, as well as the recombinant protein (**Figure 4**). Western blots stained with antibodies generated against the native 32 kD binding protein detected the 62, 32, 30, 17, and 16 kD polypeptides, in addition to the recombinant protein (**Figure 4**). The antibody to the recombinant fusion protein or the native 32 kD polypeptide stained homogenates of the adult rat cerebellum, but was of a notably lesser density than in the 6-day specimen (**Figure 4**).

Immunocytochemistry

Immunocytochemistry was performed using methodology described previously (Zagon et al., *Brain Res.* 803: 61-68, 1998). In brief, rat brains from 6-day old and adult animals were frozen and sectioned.

Adjacent sections were stained with antibodies to 14-GST fusion protein or with polyclonal antibodies to the OGF binding protein. Controls included staining sections with primary antibodies preabsorbed with either 14-GST fusion protein or with OGF binding protein, as well as secondary antibodies only.

The staining pattern in immunocytochemical preparations employing antibodies to the recombinant

fusion protein was similar to that observed when using antibodies to the authentic binding protein (**Figure 5**). Both antibodies revealed immunoreactivity in the 6-day old rat cerebellum, with cells of the external germinal layer exhibiting prominent staining of the cytoplasm and low reactivity of the nucleoplasm. The internal granule cells of adult rat cerebellar tissues demonstrated little specific immunoreactivity with either antibody.

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Example 3

Regulation of Cell Growth Using Rat OGF α r Antisense DNA

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In order to study the function of the isolated cDNA with respect to growth, a 23-mer antisense S-ODN (nuclease-resistant phosphorothioate; Oligo, Etc., Bethel, ME) targeted against a sequence containing the translation initiation site of the OGF binding protein was designed: 5'- GACTCAGGGACTTAGCTTCATCC-3' (antisense, SEQ ID NO: 15). A 23-mer with a scrambled sequence was also designed: 5'-ATAGATACTACGCCGGCTGTCCT-3' (scrambled, SEQ ID NO: 16).

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The IEC-6 rat small intestine epithelial cell line (American Type Tissue Culture Collection, Manassas, VA) were grown in Dulbecco's medium supplemented with 10% fetal calf serum. For experiments, 5×10^3 cells/well in a 24-well plate were seeded and, 24 hr later, 10^{-6} M concentrations of the antisense or the scrambled S-ODN were added. Some wells were exposed to 10^{-6} NTX or an equivalent volume of sterile water. Media, S-ODNs, or drugs were changed daily. After 72 hr in culture, cells were trypsinized, stained with trypan blue, and counted with a hemacytometer; 3 wells/treatment group were assessed. The data were evaluated with ANOVA, and subsequent comparisons were made with the Newman-Keuls tests.

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As shown in **Figure 6**, the antisense S-ODN elevated cell number by 294% from control cultures within 48 hr of exposure. The cell cultures treated with the scrambled probe were similar in growth to control levels. Cultures treated with NTX, an antagonist to the opioid

Example 4

Isolation of cDNA Encoding a Human OGF Binding Protein

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A fragment of the human OGFr cDNA was obtained by reverse transcriptase - polymerase chain reaction (RT-PCR) using mRNA from a pool of 24 male/female, 20-25-week old human fetal brains obtained from spontaneous abortions (Clontech, Palo Alto, CA). Primers were generated from the rat cDNA sequence (clone #12, Example 1). A RT-PCR product of 400 nucleotides (as predicted) was amplified and designated "H5". Homology with rat OGFr was confirmed by Southern blot analysis using [³²P]-dCTP labeled rat clone #12. H5 was cloned using the TOPO TA cloning kit (Invitrogen, Carlsbad, CA) and sequenced. RNA from a variety of human tissues was probed with [³²P]-dCTP labeled H5, and revealed that the greatest amount of target mRNA was associated with human placenta.

Binding assays were performed on human placenta using radiolabeled [Met⁵]-enkephalin to characterize this tissue. Binding studies with human placenta and radiolabeled [Met⁵]-enkephalin revealed specific and saturable binding, with a mean binding affinity (K_d) of 12.3 ± 3.9 nM and a binding capacity (B_{max}) of 247 ± 95 fmol/mg protein (**Figure 7**). A one-site model of binding was noted.

Using human placental mRNA (Clontech), the complete sequence of human OGFr was assembled with a combination of 3'- and 5'-RACE techniques performed with a Marathon cDNA Amplification Kit (Clontech). RACE products were cloned utilizing a TOPO TA cloning kit (Invitrogen) and sequenced by an automated sequencer (ABI

Prism Model 377 Version 2.1.1) located in the
MacroMolecular Facility of The Pennsylvania State
University College of Medicine. Sequence data were
analyzed with the Sequence Analysis Software Package of
the Genetics Computer Group (University of Wisconsin
Biotechnology Center).

5' RACE consistently yielded a single species
of cDNA, while the 3' RACE revealed extensive alternative
splicing. When assembled, the longest predicted cDNA
(designated clone 8 for the particular 3' clone found
with a given structure) was 2.4 kb. **Figure 8A** shows the
nucleotide (SEQ ID NO: 5) and the deduced amino acid
sequence (SEQ ID NO: 6) of this cDNA; 5' and 3'
untranslated regions have been included. The open
reading frame was found to encode a protein of 697 amino
acids, and 8 imperfect repeats of 20 amino acids were a
prominent feature. The predicted initiation site was
flanked by a strong Kozak consensus sequence. A number
of alternate spliced forms were detected by 3' RACE, and
these are depicted in **Figure 8B-D**. Two of the alternate
spliced forms (clones #1 and 127) were missing the
imperfect repeats (**Figure 8C**). Clones #4, 7, and 8
differed only in the number of imperfect repeats (**Figure
8D**).

Sequence similarity was compared to the entries
recorded in the GenBank database using FASTA and BLAST
databases.

The chromosomal location of the human receptor
for OGF was determined by FISH as 20q13.3 (**Figure 8E**).

Example 5
Expression Pattern of Human OGF α r

5 Northern blot analysis of human fetal and adult tissues, as well as cancer tissues and cell lines, was performed with a **radiolabeled OGF α r cDNA cocktail** according to the procedure described by McLaughlin and Allar (*Mol. Brain Res.* 60: 160-167, 1998).

10 Briefly, commercially prepared blots of poly A⁺ RNA from human tissues and cells were obtained from Clontech (Palo Alto, CA). RNA samples of fetal tissue (Human Fetal II Multiple Tissue Northern (MTNTM) Blot, Lot. #080009) were pooled from tissues ranging from 7 to
15 32 individuals that were 16 to 32 weeks in age, and representative of both genders. The cause of death was spontaneous abortion. The blot of human tissues (Human Multiple Tissue Northern (MTNTM) Blot, Lot #8070732) contained pooled samples from 2 to 18 individuals that
20 were 10 to 69 years in age and, except for the heart (males) and placenta (females), was representative of both genders. In the case of the liver, the tissue was obtained from a 35-year-old male. With the exception of the placenta, the causes of death were reported as sudden
25 death (brain, lung, liver, and skeletal muscle) or trauma (heart, kidney, and pancreas). A Human Cancer Cell Line Multiple Tissue Northern (MTNTM) Blot (Lot #9050001) was purchased from Clontech and contained: promyelocytic leukemia, HL-60, HeLa cell S3, chronic myelogenous
30 leukemia K-562, lymphoblastic leukemia MOLT-4, Burkitt's lymphoma Raji, colorectal adenocarcinoma SW480, lung carcinoma A549, and melanoma G361. Cancer cell lines

were purchased from the American Type Tissue Collection (Manassas, VA) and included: human pancreatic cancer cell lines BxPC3, PANC-1, and MIA PaCa-2, squamous cell carcinoma of the head and neck CAL-27, and neuroblastoma SK-N-SH. Human pancreatic total RNA was purchased from InVitrogen (Lot #7110156). Surgical specimens of human tissues included: squamous cell carcinoma of the tongue (65-yr-old male, Stage III), renal cell carcinoma and normal kidney (73-yr-old male, radical nephrectomy).

Total RNA was prepared by immersing preparations in ice-cold 4 M guanidinium isothiocyanate/0.83% β -mercaptoethanol/0.3 M sodium acetate and homogenizing with a polytron (setting 6, 2 x 10 sec). Homogenized tissues were layered over a cushion of 5.7 M cesium chloride/0.3 M sodium acetate and centrifuged at 105,000 x g with an SW55Ti rotor for 18 hr at 25°C. Total RNA was precipitated with ethanol, and quantitated by UV spectrometry. Inasmuch as possible, equal amounts of total RNA were subjected to electrophoresis on 1.0% agarose-2.5% formaldehyde gels, transferred by capillary blotting to nylon membranes, and baked in vacuo at 80°C for 1 hr. Filters were prehybridized for 4-8 hr at 42°C in a solution containing 50% deionized formamide, 5 X Denhardt's buffer (50 X Denhardt's = 5 g Ficoll, 5 g polyvinylpyrrolidone, and 5 g bovine serum albumin in 500 ml sterile water), 50 mM sodium phosphate, pH 6.5, 5 X SSC (20 X SSC = 3 M sodium chloride and 0.3 M sodium citrate), 500 mg/ml salmon sperm DNA (Sigma) and 1% SDS.

Membranes were hybridized at 42°C for 22 hr in fresh prehybridization buffer containing 10^6 cpm/ml of random primed human cDNAs. Filters were subjected to

final washes at 60°C with 0.1 X SSC containing 0.1% SDS for 30 min, and wrapped in plastic while wet, and exposed to autoradiography film with intensifying screens for 2-4 days at -70°C. To control for differences in the amount of RNA loaded, as well as the integrity of RNA, blots were stripped and probed with [³²P]-labeled cDNA for β-actin (Clontech).

As shown in **Figure 9**, in the human fetal tissues, transcript sizes of 1.7 and 2.4 kb were observed, whereas in the adult tissues and cancer cell lines and tissues only a 2.4 kb mRNA was detected. Receptor for OGF was of low abundance only in adult lung.

Example 6

Regulation of Cell Growth Using Human OGF α r Antisense DNA

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To study the function of the isolated cDNA with respect to regulation of cell growth, a 23-mer antisense S-ODN (nuclease-resistant phosphorothioate; Oligo, Etc., Bethel, ME) targeted against a sequence containing the translation initiation site of the OGF binding protein was designed: 5'-GGTCGTCCATGCTCGGCTAGAAT-3' (antisense, SEQ ID NO: 17). A scrambled (control) S-ODN was also designed: 5'-GTGCAGTGCAATGCTCTCCGTGA-3' (SEQ ID NO: 18).

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The SK-N-AS human neuroblastoma cell line (American Type Tissue Culture Collection, Manassas, VA) was grown in Dulbecco's medium supplemented with 10% fetal calf serum. For experimentation, 6×10^3 cells/well in a 24-well plate were seeded and, 24 hr later, 10^{-6} M concentrations of the antisense or the scrambled S-ODN was added. Some wells were exposed to 10^{-6} M NTX or an equivalent volume of sterile water. Media, S-ODNs, or drugs were changed daily. After 72 hr in culture, cells were trypsinized, stained with trypan blue, and counted with a hemacytometer. Data from the antisense experiments were evaluated with ANOVA, and subsequent comparisons made with the Newman-Keuls tests.

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As shown in **Figure 10**, the antisense S-ODN elevated cell number by 60% from control cultures within 48 hr of exposure. The cell cultures treated with the scrambled probe were similar in growth to control levels. Cultures treated with NTX, an antagonist to the opioid

binding protein, also had increased cell growth from control values.

Example 7

Characterization of OGFr in Human Pancreatic Adenocarcinoma

Materials and Methods

Cell culture. PANC-1, Mia PaCa-2, BxPC-3, and Capan-1 cell lines were obtained from the American Type Culture Collection (Manassas, VA). Specific characteristics of each human pancreatic tumor cell line have been reported previously (Zagon et al., *Int. J. Oncol.* 14: 577-584, 1999). PANC-1 and MIA PaCa-2 cells were maintained in Dulbecco's modified media, while Capan-1 and BxPC-3 cells were grown in RPMI media; all media contained 10% fetal calf serum, 2 mM L-glutamine, 1.2% bicarbonate and antibiotics (5,000 Units/ml penicillin, 5 mg/ml streptomycin, 10 mg/ml neomycin). Cells were grown in a humidified atmosphere of 5% CO₂/95% air at 37°C. Panc-1 cells between passages 62-74 were used for the characterization studies.

Preparation of protein fractions. Cell cultures were harvested by scraping of the flasks, and cells were pelleted by centrifugation. The washed pellet was homogenized (Polytron, setting 5, 2 x 10 sec) in a 1:20 (wt/vol) solution of cold 50 mM Tris-HCl with 0.1 mg/ml bacitracin, 1 mg/ml leupeptin, 6 nM thiorphan, 1 mM EGTA, and 3.5 mM PMSF (pH 7.4) at 4°C; this buffer is termed Tris/all. Homogenates were layered over a 1.4 M sucrose cushion, and centrifuged (2,200 g) for 20 min; this step was conducted twice in order to obtain a nuclear pellet (P1).

For subcellular fractionation studies, the supernatant of P1 was centrifuged at 39,000 x g for 30

min to obtain a plasma membrane pellet (P2). The P2 supernatant was centrifuged overnight (100,000 x g), resulting in a microsomal pellet (P3) and soluble supernatant (S3). All fractions were inspected for purity by phase-contrast microscopy.

Receptor binding assays. Homogenates of nuclear protein were diluted with Tris/all to the appropriate protein concentration and incubated at room temperature (22°C) for 20 min to remove endogenous peptides. Aliquots of protein were resuspended to 0.95 ml and incubated with agitation with radioactive ligand. Saturation assays were conducted with various concentrations of ligand, usually ranging from 0.1 to 15 nM. The final volume of the incubation mixture was 1 ml. Isotope incubation was terminated by rapid filtration through Whatman GF-B filters under vacuum pressure with a Brandel Cell Harvester. Filters were rinsed with ice-cold Tris/all buffer, dried at 60°C for 1 hr and counted by liquid scintillation spectrometry (Beckman LS-2800). Nonspecific binding was determined in the presence of 100 nM of [Met⁵]-enkephalin. Duplicate tubes of homogenates were assayed for each concentration utilized. Protein concentrations were determined by the BioRad method with g-globulin as the standard.

For competition studies, nuclear homogenates were incubated with 1 nM radiolabeled [Met⁵]-enkephalin and a range of concentrations (10^{-4} to 10^{-10} M) of each of the non-labeled compounds. Each concentration was run in triplicate and every compound was tested twice.

Analysis and statistics. Receptor binding data were analyzed with either the Lundon I (Saturation Isotherm Binding Analysis) computer program (Lundon

Software, Cleveland, OH) or GraphPad Prism software. Both programs utilize nonlinear least-squares regression. Binding isotherms and Scatchard plots were computed directly by the programs. Competition data were analyzed by the Lundon II competition data-analysis program, and the inhibition constant was calculated from the half-maximal displacement (concentration inhibiting 50% of maximal response) values using the method of Cheung and Prusoff (*Biochem. Pharmacol.* 22: 3099-3108, 1973). Comparisons of B_{\max} and K_d values were made using analysis of variance and posthoc Newman-Keuls tests.

Characterization of [^3H]-[Met 5]-enkephalin binding

The optimal conditions for binding of [^3H]-[Met 5]-enkephalin (OGF) to PANC-1 nuclear (P1) homogenates were determined. Specific binding of radiolabeled ligand to PANC-1 nuclear homogenates was dependent on protein concentration and was linear between 200 and 550 mg/ml (**Figure 12**). Binding of [^3H]-[Met 5]-enkephalin to P1 homogenates of PANC-1 cells was also dependent on time and temperature of incubation (**Figure 13**). Maximal specific binding occurred at 22°C, reaching an equilibrium between 60-75 min. Binding at 0°C and 37°C was 12% and 21%, respectively, of the optimal binding at 22°C. The binding of radiolabeled [Met 5]-enkephalin was also dependent on pH of the buffer solution, with an optimal pH of 7.4 being recorded (**Figure 14**).

The effects of monovalent and divalent cations on [^3H]-[Met 5]-enkephalin binding to PANC-1 nuclear homogenates are presented in **Figure 15**. Addition of NaCl, CaCl $_2$, and MgCl $_2$ at concentrations of 50, 100, or 200 mM reduced specific radioactive binding by as much as

85%. The binding of [³H]-[Met⁵]-enkephalin was not markedly altered by addition of 50, 100, or 200 μM GppNHp to the binding assays.

By use of the optimal conditions for protein concentration, time, temperature, and pH described above, in a buffer containing a cocktail of protease inhibitors, [³H]-[Met⁵]-enkephalin binding to PANC-1 nuclear homogenates (P1 fraction) was found to be specific and saturable (**Figure 16**). Computer analysis of binding showed that the data best fit a one-site binding model with an average equilibrium dissociation constant (K_d) of 1.2 ± 0.3 nM and a mean maximal binding capacity (B_{max}) of 36.4 ± 4.1 fmol/mg protein. Nonspecific binding was calculated to be ~52% of the total binding.

Competition assays

Competition experiments using 1 or 2 nM [³H][Met⁵]-enkephalin and a range of natural and synthetic opioid peptides were performed to examine the specificity and relationship of radiolabeled [Met⁵]-enkephalin to its binding site (**Table I**). [Met⁵]-enkephalin exhibited the greatest potency of any of the compounds tested, having 100-fold greater ability to displace [³H][Met⁵]enkephalin than the next ranking compound; the competition value (IC_{50}) for [Met⁵]-enkephalin was 5.5 nM. Ligands related to the μ- (i.e., DAMGO), δ- (i.e., DPDPE, ICI-174,468), κ- receptors (i.e., dynorphin A, U69,598, ethylketocyclazocine), and well as morphine and leucine enkephalin exhibited little or no competition.

Table I.

Potency of prototypic opioid ligands to compete for binding of [³H]-[Met⁵]-enkephalin in nuclear homogenates of human pancreatic tumor cells (PANC-1).

	Compound	IC ₅₀ /K _d
5 10	μ Receptor	DAMGO
	δ Receptor	DPDPE
		ICI-174,568
	κ Receptor	Dynorphin A1-8
		U69,598
15		EKC
	Other ligands	Morphine
		Leucine enkephalin
		β-endorphin

Data represent values from at least 2 independent assays. Equilibrium dissociation constant for [Met⁵]-enkephalin was 1.2 ± 0.3 nM. IC₅₀ is the concentration that inhibits 50% of maximal response; K_d is the inhibition constant. DAMGO = [D-Ala², N-Me-Phe⁴, Gly⁵-ol]-enkephalin, DPDPE = [D-Pen², Pen⁵]-enkephalin, EKC = ethylketocyclazocine.

Subcellular fractionation studies

Sucrose gradient centrifugation was performed to separate the nuclear (P1), membrane (P2), microsomal (P3), and soluble (S3) fractions (Table II). In these experiments, specific and saturable binding of [³H]-[Met⁵]-enkephalin was detected in the P1 fraction, and computer analysis revealed a one-site model of binding with a K_d of 2.3 ± 0.5 nM and B_{max} of 21.8 ± 4.8 fmol/mg protein. No specific and saturable binding was detected in fractions enriched in the P2, P3, or S3 fractions.

Table II.

Subcellular fractionation studies utilizing [³H]-[Met⁵]-enkephalin and PANC-1 human pancreatic cells.

Fraction	Cellular Composition	K _d , nM	B _{max} (fmol/mg protein)
P1	Nuclear	2.3 ± 0.5	21.8 ± 4.8
P2	Membranes	NB	NB
P3	Microsomal	NB	NB
S3	Soluble	NB	NB

Values represent means ± SE for 3 independent assays. K_d, dissociation constant; B_{max}, binding capacity. NB = no specific or saturable binding.

Stage of growth on PANC-1 cells

PANC-1 cells grown for 3 to 4 days (log phase), 6-7 (confluent), or 9 days (post-confluent) were assayed for binding to radiolabeled [Met⁵]-enkephalin (Table III). The length of time in culture had no effect on the affinity of [³H]-[Met⁵]-enkephalin. However, in contrast to post-confluent cells, the binding capacity of radiolabeled [Met⁵]-enkephalin was reduced by 42% and 78% from the log-phase and confluent cultures, respectively.

Table III.

Binding of [³H]-[Met⁵]-enkephalin and PANC-1 human pancreatic cells at different stages of growth.

Days in culture	K _d , nM	B _{max} (fmol/mg protein)
Log phase 3	4.2 ± 2.1	20.7 ± 1.2
Confluent 5	5.3 ± 0.0	7.8 ± 0.0**
Post-confluent 7-8	13.1 ± 1.1	35.6 ± 0.3**

Values represent means \pm SE for 3 independent assays.
 K_d , dissociation constant; B_{max} , binding capacity.
**Significantly different from log phase at $p < 0.01$.

5

Ubiquity of OGFr in pancreatic cancer cell lines and xenografts

10 To examine for the presence of OGFr in a variety of pancreatic adenocarcinoma, saturation binding isotherms were performed on nuclear homogenates obtained from log phase BxPc-3, MIA PaCa-2, Capan-1, and Capan-2 cells (**Table IV**). The K_d ranged from 1.2 to 10.8 nM, and the B_{max} ranged from 11.9 to 25.5 fmol/mg protein.

15 Xenografts of human pancreatic cancer were performed according to earlier procedures (Zagon et al., *Cancer letters* 112: 167-175, 1997). In brief, 200,000 log-phase Capan-1 were injected subcutaneously into 4-week-old athymic nude mice (Charles River Laboratories, 20 Wilmington, MA). Tumor tissue was harvested 40 days after cell inoculation. Xenografts of Capan-1 growing in nude mice revealed a K_d of 2.9 ± 1.5 nM and a B_{max} of 4.2 ± 1.1 fmol/mg protein.

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Table IV.

Specific binding for [3 H]-[Met 5]-enkephalin to nuclear fractions of a variety of human pancreatic cancer cell lines.

30

Cell Line	State of Differentiation	K_d , nM	B_{max} , fmol/mg
MIA PaCA-2	Moderately to well	10.8 ± 5.5	11.9 ± 1.5
Capan-1	Metastatic to liver	6.5 ± 4.1	22.7 ± 9.5
BxPC-3	Moderately to well	1.2 ± 0.3	25.5 ± 9.7
PANC-1	Poor	5.1 ± 1.4	28.9 ± 6.2

Values represent means \pm SE for at least 3 independent assays. K_d , dissociation constant; B_{max} , binding capacity.

5

OGFr in neoplastic and normal pancreatic tissues

Tumor specimens were obtained at the time of pancreatic resection from four females ranging in age from 52- to 66-yrs, and a 67-yr-old male. Normal tissues (as determined from histological assessment) were obtained from two females (61- and 66-yr-old) and a male (55-yr-old). In the case of the normal samples from the two females, the specimens were adjacent to the tumor tissue. All human tissue specimens were collected with the approval of the Institutional Review Board, Human Subjects Protection Office, The Pennsylvania State University College of Medicine. Samples were collected and frozen in liquid nitrogen within 1 hr of surgery. Receptor binding assays were performed as stated above.

Human pancreatic cancer obtained at resection showed a mean K_d of 2.1 ± 1.0 nM and a B_{max} of 6.6 ± 1.2 fmol/mg protein for the specimens harvested from 3 patients; in 3 specimens, non-specific and non-saturable binding were recorded. Of the 3 normal specimens of human pancreas, a mean K_d of 9.6 ± 2.9 and B_{max} of 46.7 ± 27.8 fmol/mg protein was detected.

Example 8

Decreased OGF_r Number in Head and Neck Squamous Cell Carcinoma Compared to Normal Mucosa

To compare the ζ opioid receptor in SCCHN versus normal mucosa, pharmacological binding assays utilizing enriched nuclear preparations of human tissue obtained from surgery and [³H]-[Met⁵]-enkephalin were conducted. Specific and saturable binding of a one-site receptor model was confirmed. Human tissue samples were representative of a variety of squamous cell carcinomas, including specimens from the oral cavity-larynx, and regional metastases. Normal mucosal specimens were obtained during uvu-lopalatopharyngoplasty. Binding capacity (B_{max}) of the radioactive ligand, and index of receptor number, was 80.8 ± 32.8 fmol/mg protein for normal epithelium in comparison to a 6-fold less B_{max} of 13.6 ± 1.9 fmol/mg protein for neoplastic specimens; these values differed significantly ($p < 0.01$). No differences in binding were noted among the carcinogenic tissues assayed. Specific affinity (K_d) values were comparable between normal and neoplastic tissues being 11.6 ± 2.5 and 4.1 ± 0.4 nM respectively. These data indicate that opioid growth factor receptor levels are reduced in human SCCHN when compared to normal mucosa. Nonetheless, the receptors are present and capable of binding ligand and with normal affinity suggesting that supplementation with exogenous OGF might be inhibitory to cancer cells.



Figure 1

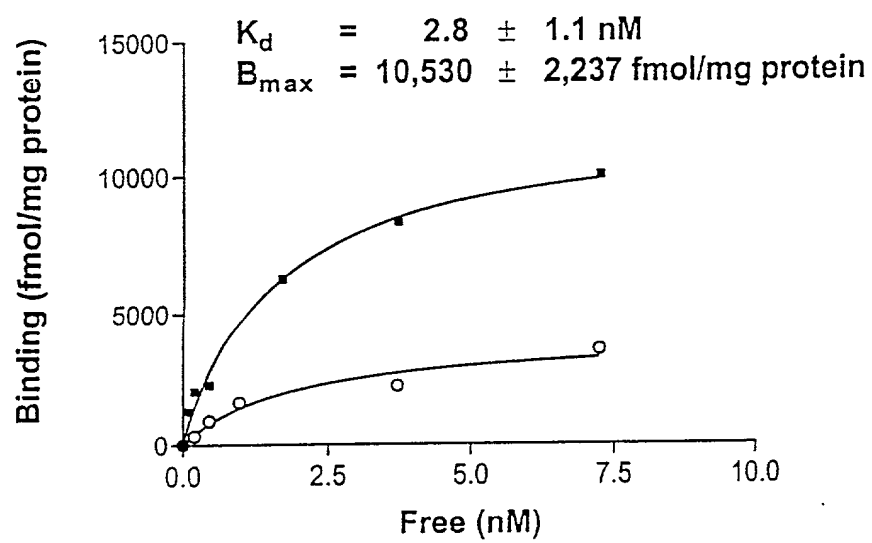


Figure 3

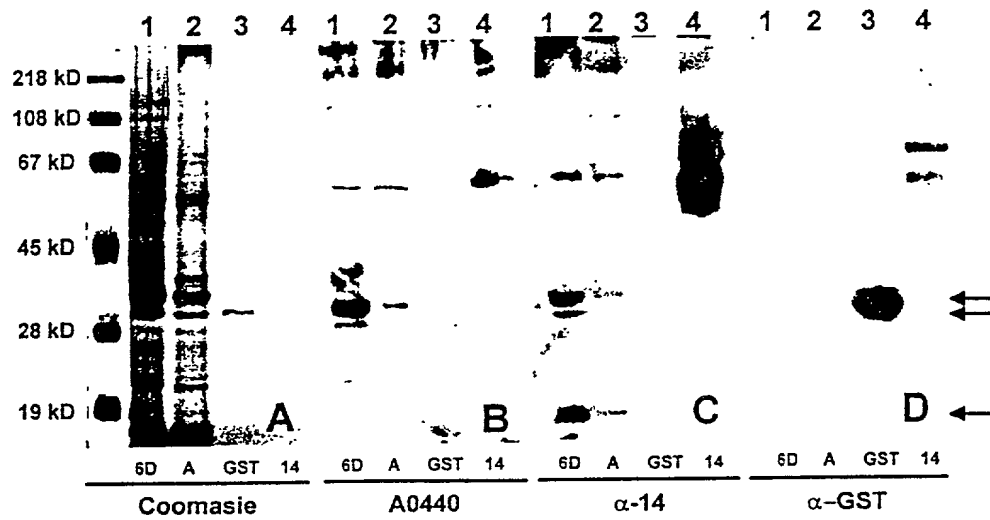


Figure 4

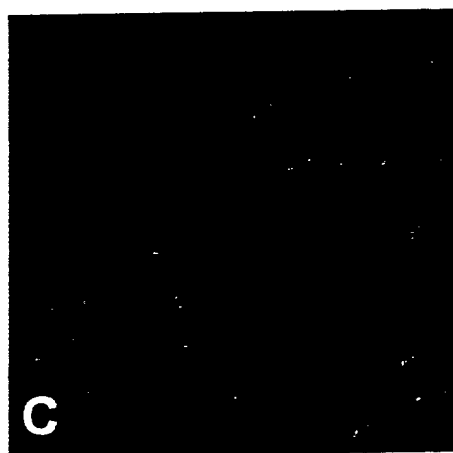
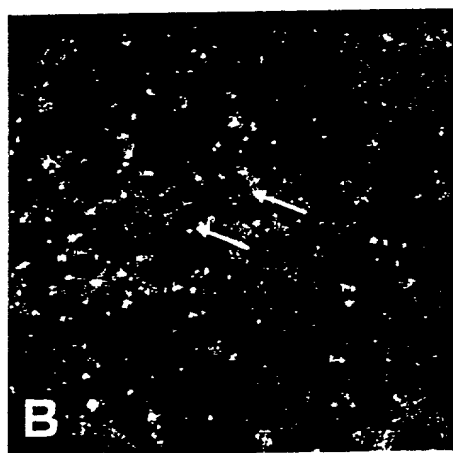
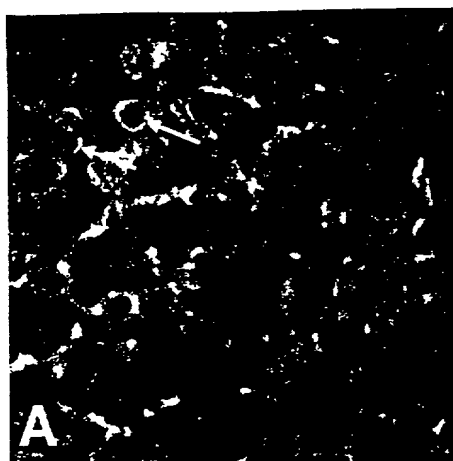


Figure 5

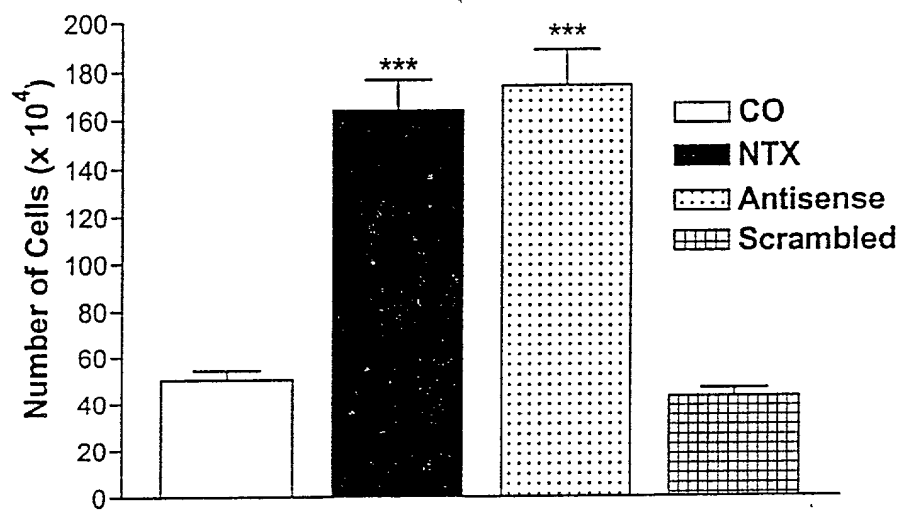


Figure 6

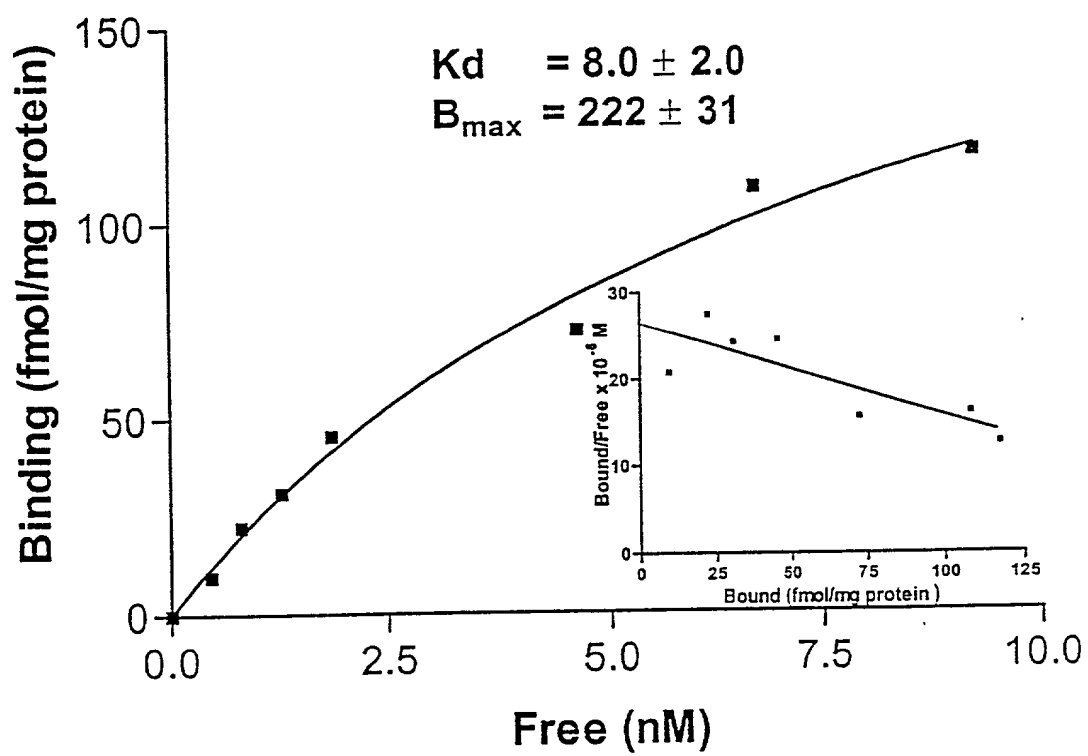


Figure 7

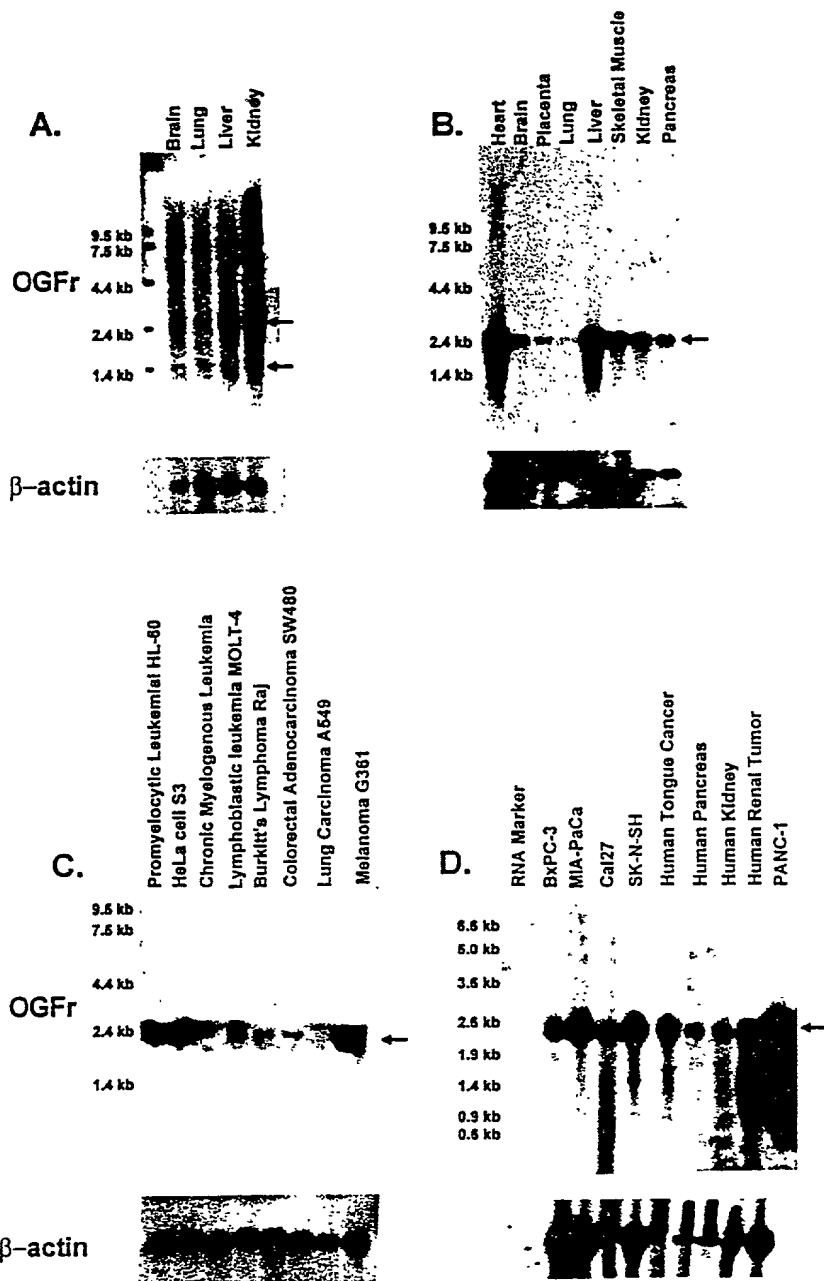


Figure 9

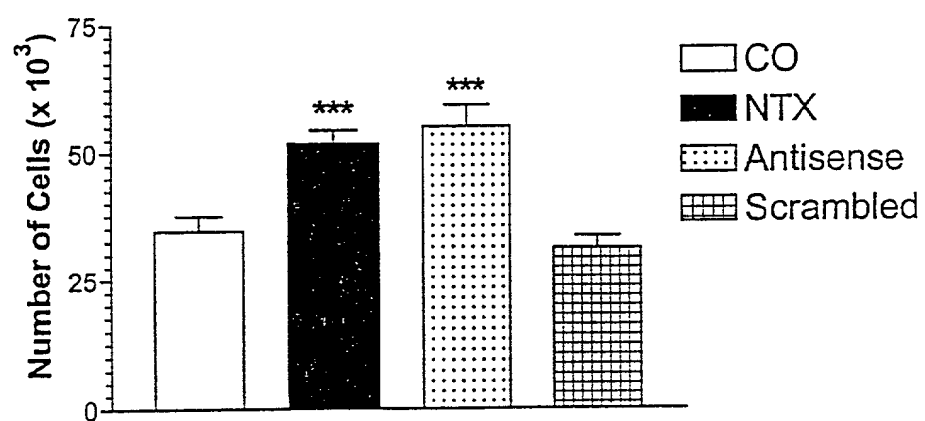


Figure 10

Human and Rat OGF_r

79% Identical/ 87% Similar		39.5% Identical/ 56% Similar	23% Identical/ 47% Similar	20% Identical/ 43% Similar
1	297	464	629	697
Amino Acid Number				

Figure 11

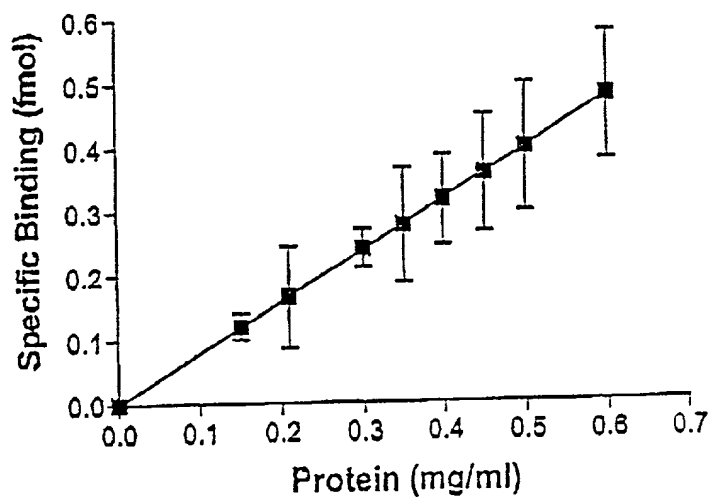


Figure 12

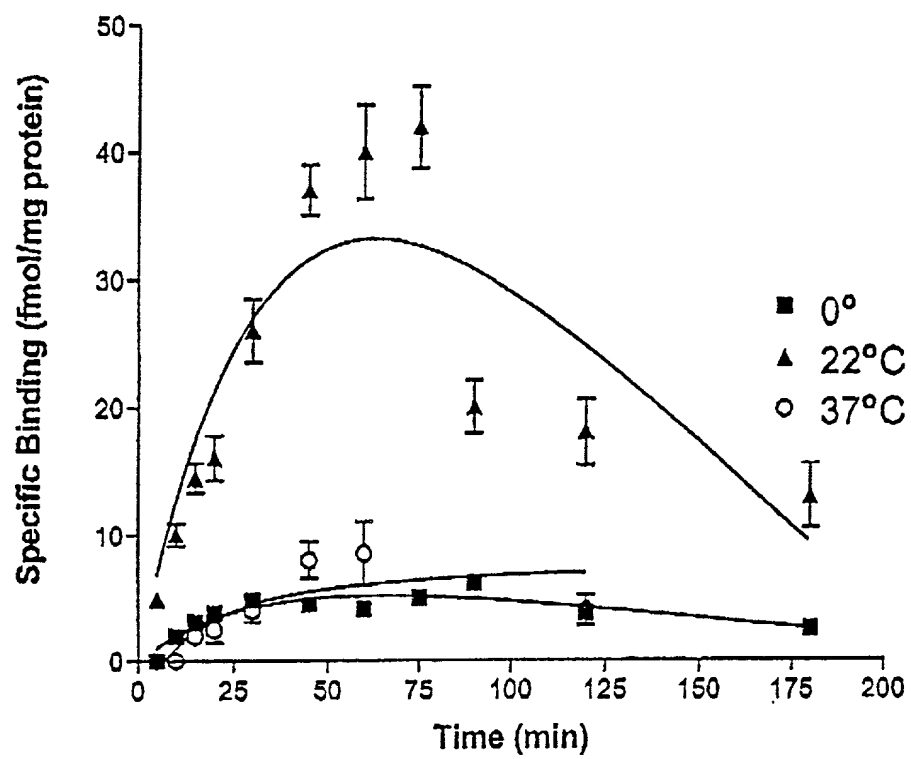


Figure 13

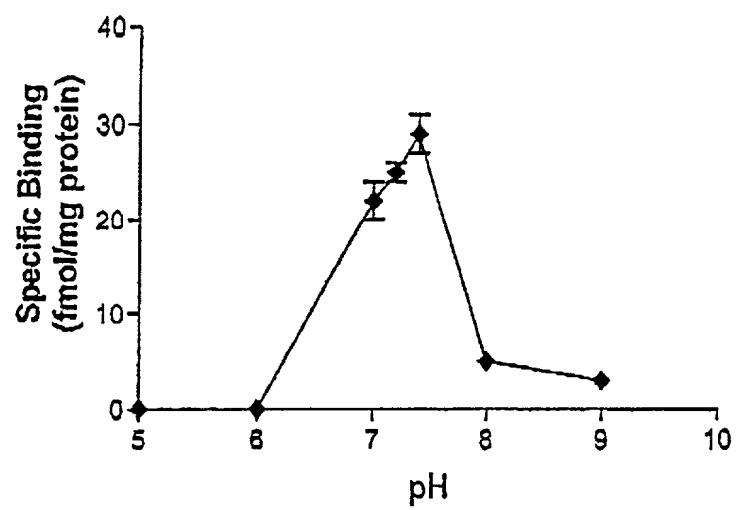


Figure 14

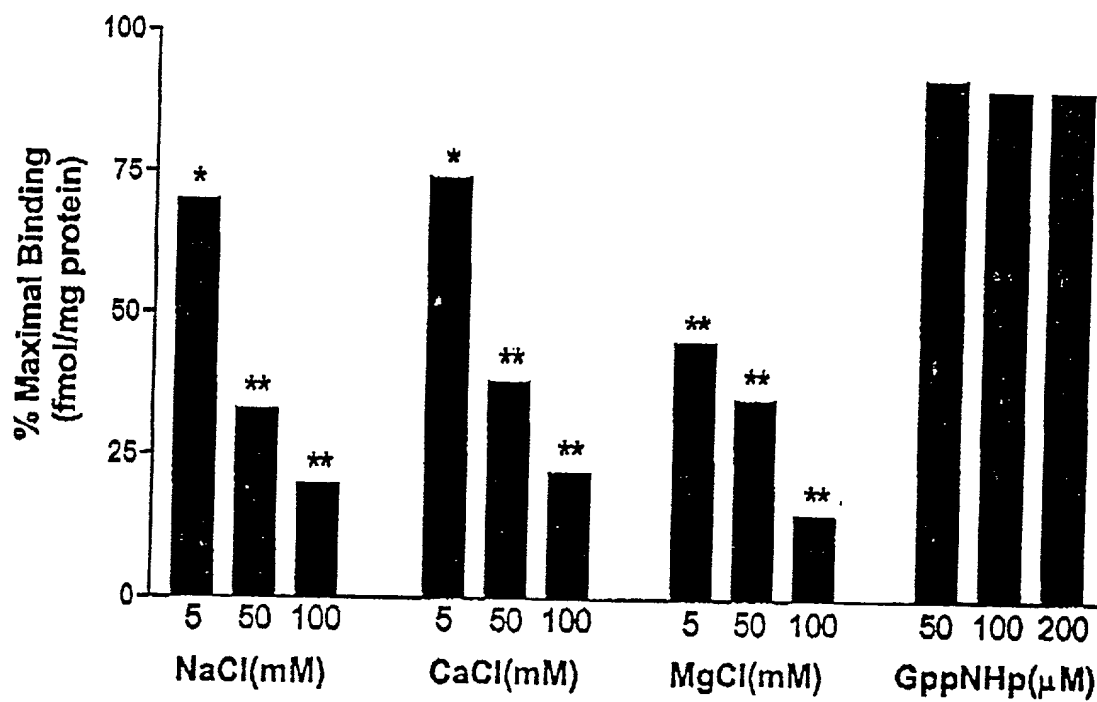


Figure 15

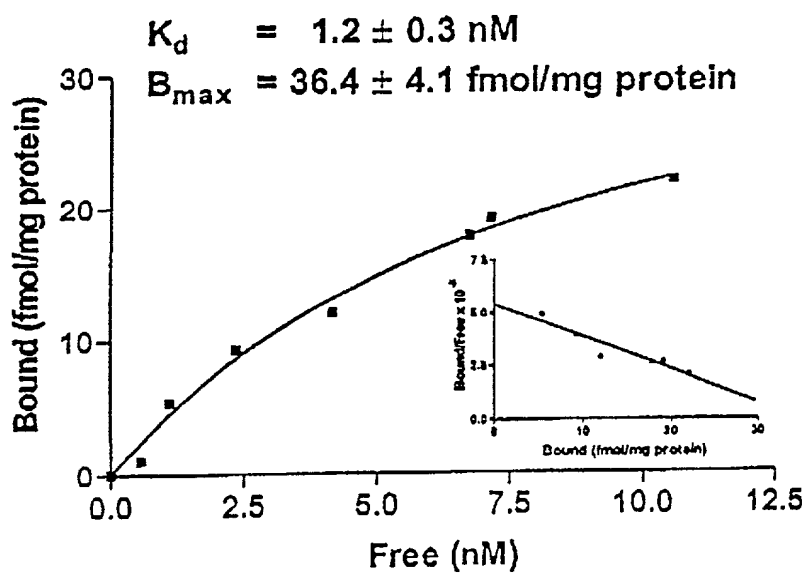


Figure 16

DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

"NOVEL NUCLEIC ACID MOLECULES ENCODING OPIOID GROWTH FACTOR RECEPTORS"

the specification of which

(check one) ☒ [XXXX] is attached hereto.

☐ was filed on _____ as United States Application Number _____
or PCT International Application Number _____ and was amended on
_____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Priority Not Claimed

_____	_____	_____	[]
(Number)	(Country)	(Day/Month/Year Filed)	
_____	_____	_____	[]
(Number)	(Country)	(Day/Month/Year Filed)	

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below.

<u>60/106,879</u>	<u>11/03/98</u>
(Application Number)	(Filing Date)
_____	_____
(Application Number)	(Filing Date)

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose material information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

_____	_____	_____
(Application Number)	(Filing Date)	(Status-patented, pending, abandoned)
_____	_____	_____
(Application Number)	(Filing Date)	(Status-patented, pending, abandoned)

60106879 110398

DECLARATION FOR PATENT APPLICATION

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Thomas J. Monahan (Reg. No. 29,835); Frank S. DiGiglio (Reg. No. 31,346)

Address all telephone calls to Thomas J. Monahan at telephone no. 814-865-6279.

Address all correspondence to Intellectual Property Office
The Pennsylvania State University
113 Technology Center
University Park, PA 16802

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor (given name, family name): IAN S. ZAGON

Inventor's signature: _____ Date: _____

Residence: Hummelstown, Pennsylvania Citizenship: U.S.A.

Post Office Address: 589 Cook Court, Hummelstown, Pennsylvania 17036

Full name of second joint inventor, if any (given name, family name): PATRICIA J. McLAUGHLIN

Second Inventor's signature: _____ Date: _____

Residence: Harrisburg, Pennsylvania Citizenship: U.S.A.

Post Office Address: 5535 Partridge Court, Harrisburg, Pennsylvania 17111

Full name of third joint inventor, if any (given name, family name): MICHAEL F. VERDERAME

Third Inventor's signature: _____ Date: _____

Residence: Hershey, Pennsylvania Citizenship: U.S.A.

Post Office Address: 1882 Sand Hill Road, Hershey, Pennsylvania 17033

Sequence Listing

SEQ ID

	1	rat OGFr cDNA	
5	2	rat OGFr protein	
	3	rat OGFr cDNA partial (clone 14)	
	4	human OGFr cDNA (Provisional)	
	5	human OGFr splice version 8, cDNA	
	6	human OGFr splice version 8, protein	
10	7	human OGFr splice version 1, cDNA	
	8	human OGFr splice version 1, protein	
	9	human OGFr splice version 4, cDNA	
	10	human OGFr splice version 4, protein	
	11	human OGFr splice version 7, cDNA	
15	12	human OGFr splice version 7, protein	
	13	human OGFr splice version 127, cDNA	
	14	human OGFr splice version 127, protein	
	15	rat OGFr antisense	5'-GACTCAGGGACTTAGCTTCATCC-3'
	16	scrambled	5'-ATAGATACTACGCCGGCTGTCCT-3'
20	17	human OGFr antisense	5'-GGTCGTCCATGCTCGGCTAGAAT-3'
	18	scrambled	5'-GTGCAGTGCAATGCTCTCCGTGA-3'

25

30

SEQ ID NO: 1 -- Rat Opioid Growth Factor Receptor cDNA sequence

```

5  TGGGCTCAGCCACGCCCCAGGGTGCCCCAGTGGGACTAGTTCTTCATTCTGGCAGCTGCACACATCTGTCTAGTGAGGAATGTCAGGTC 90
   TCTCACTCTCCTCTCCTCACTATCCTTTCCGCAGAAAGCGGGTCCTCTGCTTGTCTGAGTATGGACGACCCGGACTGCGATTCCACCTGG 180
   GAGGAGGAGAGCGAGGAGGATGGCGAGGATGGCCAGGCGGATGATACGACCGATGAGGACACGGGCGACGATGACGGCGACGCGGAGGAG 270
   GCACGGCCAAGCCTGTTCCAGTCCAGGATGACAGGGTACCGAACTGGCGTGCTATGCAGGACATGCAAAGATACCGGCACAACTACCCG 360
   GATTTGACAGATCAAGACTGCAATGGTGACATGTGCAACCTGAGCTTCTACAAAAATGAGATCTGCTTCCAGCCAAATGGGGCTCTCATC 450
   GAGGACATTCTTCAGAACTGGAAAGACAACATATGACCTCCTGGAAGAGAATCACTCCTACATCCAGTGGCTGTTTCTCTGCGGGAACCA 540
   GGAGTGAAGTGGCAGCGCAAGCCCCCTCACCTGAAGGAGGTTGAGGCATTTAAAGCTCCAAGGAAGTCAGAGAGCGTCTTGTCCGGGCC 630
10  TATGAGCTCATGCTGGGCTTCTATGGGTTCCACCTTGAGGACCGGGGCACGGGTGCTGTATGCCGTGCACAGAACTCCAGCCGCGCTTC 720
   CACAATCTGAACAGCCACAGCCACAACAACCTGCGTATTACACGCATCCTCAAGTCACTGGGTGAGCTGGGCTTAGAACACTACCAGGCA 810
   CCCCTGGTCCGCTTCTTCTGGAGGAGACCTTGTACAGCACAACCTGCCAGCGTGCGCCAGAGTGGCCTGGACTACTTCTGTTCGCT 900
   GTGCGCTGCCGGCACCAGCGCGGGAGCTTGTGTACTTTGCCTGGGAGCACTTCAAGCCTCGCCGAGAGTTTGTCTGGGGGCCCCGTGAC 990
   AAGCTGCGGAGATTCAAGCCCCAGACCATACCCCAGCCACTGACGGGACCAGGGCAGGCAGATAAAGATGAGGGCTCCAGGGACCCCTCC 1080
15  CAAGAGGCTGGCAGCCAGGGTCGGACCTGTGGATCTGGAAGGGACCTGAGTGGGGACAGTGGAACAGCTGAGGATCCCTCACTGCTGAAC 1170
   ACAAGCCCTCAGATGGGGGAACCTTGGATGGGAACAGAGGGATGAAGCTAAGTCCCTGAGTCCCAAGGAGAGCAAGAAAAGGAAGTTG 1260
   GAGGGGAACAGGCAGGAGCAGGTCCAGGGGAGGCAGATCCCCAGGGTGCTCTGAGGTAGAGAAAATTGCCCTTAACCTTGAGGAGTGT 1350
   GCCCTTAGCCCTATCAGCCAGGAGCCAGGAGGCTGAACCGCCCTGTCTGTGCGCCAGGGTGGCTAATGAGGTAAGAAAGCGGAGGAAG 1440
   GTGGAGGAAGGGGCTGAGGGTGTATGGAGTAGTCACTAACAACCTCAATGCAGGCCAGTGCCCTGCCCTCCTACCCCTTCAGAGTGTCTTGTAG 1530
20  GCCCCAAAGGATGGGAATGGGCCAGAGGACTCAACAGCCAGGTTGGGGCAGAGGATTCCAAAGCCAGGTGGGGCCGAGGATCCAAAC 1620
   AGCCAGGTGGGGCTGGAGGACCCAAACAGCCAGGTGCGGGCCAGAGGACCCAAACAGCCAGGTGCGGGCCAGAGGACCCAAACAGCCAGGTC 1710
   GGGCCAGAGGACCCAAACAGCCAGGTGCGGGCCAGAGGACCCAAACAGCCAGGTGGTGGGGCCAGAGCAAGCTGCCTCTAAGAGCCCTGTG 1800
   GAGGACCCTGACTCTGACACTATGGGAACCTCAGTGAGTGTGAGGAGTGGCAAGGATTGAGGCCTCTGCTGAACCCCAAGCCT 1890
25  TAGAGGTGCATCTCAGTCTACTCAGCCCACTGCAGGGGGTTTCTGAGTCCAGAGCTCTGCCGTAGGCTCTTCTTGGTGCCCCACAGTGC 1980
   TGGCCTCTCCCTAGTGGTCACTGAGGTGGCCACCAGAGGACTGAGGCCTGCCCTCAGGGAAGGCCAAGGCCTTCAGAACCCTCCTTAC 2070
   CTCAGTGTCTCTCTCCACTGCCCTCTGAGCCCTGCGTGTGTATCAGACCTAAGGGTCTAGAGGGAGGGCCTCTTCATTAGTCTGGT 2160
   GCCAAGTGAGGCCTTTTCTGAATAAACTCTTTAGACTTTGTCAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA 2250

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Initiator AUG at 151-153

30 Terminator TAG at 1891-1983

Open reading frame 151 (AUGGACGAC...) to 1890 (... AAGCCT)

SEQ ID NO:2 -- Rat Opioid Growth Factor Receptor

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35  1  MDDPDCDSTW  EESEEDGED  GQADDTTDED  TGDDDGDAEE  ARPSLFQSRM
    51  TGYRNWRAMQ  DMQRYRHNYP  DLTDQDCNGD  MCNLSFYKNE  ICFQPNGALI
    101 EDILQNWKDN  YDLLEENHSY  IQWLFPLREP  GVNWHAKPLT  LKEVEAFKSS
    151 KEVRERLVRA  YELMLGFYGF  HLEDRTGAV  CRAQNFQPRF  HNLNSHSHNN
40  201 LRITRILKSL  GELGLEHYQA  PLVRFFLEET  LVQHKLPSVR  QSALDYFLFA

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251 VRCRHQRREL VYFAWEHFKP RREFVWGPRD KLRRFKPQTI PQPLTGPGQA
 301 DKDEGSRDPS QEAGTQGRTC GSGRDLSGDS GTAEDPSLLN TKPSDGGTLD
 351 GNQRDEAKSL SPKESKKRKL EGNRQEQVPG EADPQGVSEV EKIALNLEEC
 401 ALSPISQEPR EAEPPCPVAR VANEVRKRRK VEEGAEGDGV VSNTQMQASA
 451 LPPTPSECPE AQKDGNGPED SNSQVGAEDS KSQVGPEDPN SQVGLDPNS
 501 QVGPEDPNSQ VGPEDPNSQV GPEDPNSQVG PEDPNSQVVG PEQAASKSPV
 551 EDPDSDTMGT SVDESEELAR IEASAEPPKP

10 SEQ ID NO:3 -- Rat OGFr, partial cDNA sequence, clone 14

1 CATTGGGCCG ACGTCGCATG CTCCTCTAGA CTCGAGGAAT TCGGGCCCCA
 51 GGGTGTCTCT GAGGTAGAGA AAATTGCCCT TAACCTTGAG GAGTGTGCCC
 101 TTAGCCCTAT CAGCCAGGAG CCCAGGGAGG STGAACCGCC CTGTCCTGTG
 151 GCCAGGGTGG CTANAATGAG GTAAGAAANG CGGNAGGAAG GTGGAGGAAG
 201 GGGCTGAGGG TGNATGGAGT AGTCAGTAAC ACTYAAATGN CAGGCCAGTG
 251 CCCTGCCTCC TACCCCTTCA GAGTGTCTCT AGGCCCAAAA GGATGGGAAT
 301 GGGCCAGAGG ACTCAAACAG CCAGGTTGGG GCAGAGGATT CAAAAGCCA
 351 GGTGGGGCCG GAGGATCCAA ACAGCCAGGT GGGGCTGGAG GACCCAAACA
 401 GCCAGGTCGG GCCAGAGGAC CCAAACAGCC AGGTCGGGCC AGAGGACCCA
 451 AACAGCCAGG TCGGGCCAGA GGACCCAAAC AGCCAGGTCG GGCCAGAGGA
 501 CCCAAACAGC CAGGTGGTGG GGCCAGAGCA AGCTGCCTCT AAGAGCCCTG
 551 TGGANGGACC CTGACTCTGA CACTATGGGA ACCTCAGTGG ATGAGTCAGA
 601 GGAGTTGGCA AGGATTGAGG CNTYTGCTGA ACCCCCAAAG CCTTAGAGGT
 651 GCATTTCACT CCTACTCAGC CCACTGCAGG GGGTTTCTGA GTCCAGAGCT
 701 CTGCCGTAGG CTCTTCTTGG TGCCCCACAG TGCTGGCCTC TCCCTASTGG
 751 TCACTGAGGT GGCCACCAGA GGGACTGAGG CCCTGCCCTC AGGGAAGGCC
 801 AAGGCCTTCA GAACCCCTCCT TACCTCACTG TGTCTCCTC CACTGCCCTC
 851 TGAGCCCTGC GTTGTGATCA GACCCTAAGG GTCTAGAGGG AGGGGCCTCT
 901 TCATTAGTCT GGTGCCAAGT GAGGCCTTTT CTGAATAAAC TCTTTAGACT
 951 TTGTCAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAA

SEQ ID NO:4 -- Human OGF receptor cDNA; spliced form A
Length: 2290

```

1  TAGAATTCAG CGGCCGCTGA ATTCTAGCCG AGCATGGACG ACCCCGACTG
5  51  CGACTCCACC TGGGAGGAGG ACGAGGAGGA TGC GGAGGAC GCGGAGGACG
101 AGGACTGCGA GGACGGCGAG GCCGCCGGCG CGAGGGACGC GGACGCAGGG
151 GACGAGGACG AGGAGTCGGA GGAGCCGCGG GCGGCGCGGC CCAGCTCGTT
201 CCAGTCCAGA ATGACAGGGT CCAGAAACTG GCGAGCCACG AGGGACATGT
251 GTAGGTATCG GCACAACAT CCGGATCTGG TGAACGAGA CTGCAATGGG
10 301 GACACGCCAA ACCTGAGTTT CTACAGAAAT GAGATCCGCT TCCTGCCCAA
351 CGGCTGTTTC ATTGAGGACA TTCTTCAGAA CTGGACGGAC AACTATGACC
401 TCCTTGAGGA CAATCACTCC TACATCCAGT GGCTGTTTCC TCTGCGAGAA
451 CCAGGAGTGA ACTGGCATGC CAAGCCCCTC ACGCTCAGGG AGGTCGAGGT
501 GTTTAAAAGC TCCCAGGAGA TCCAGGAGCG GCTTGTCCGG GCCTACGAGC
15 551 TCATGCTGGG CTTCTACGGG ATCCGGCTGG AGGACCGAGG CACGGGCACG
601 GTGGGCCGAG CACAGAACTA CCAGAAGCGC TTCCAGAACC TGAAGTGGCG
651 CAGCCACAAC AACCTCCGCA TCACACGCAT CCTCAAGTCG CCGTGTGAGC
701 TGAGCCTCGA GCACTTCCAG GCGCCACTGG TCCGCTTCTT CCTGGAGGAG
751 ACGCTGGTGC GCGGGGAGCT GCCGGGGGTG CGGCAGAGTG CCCTGGACTA
20 801 CTTTCATGTT GCCGTGCGCT GCCGACACCA GCGCCGCCAG CTGGTGCACT
851 TCGCCTGGGA GCACTTCCGG CCCCCTGCA AGTTCGTCTG GGGGCCCCAA
901 GACAAGCTGC GGAGGTTCAG GCCCAGCTCT CTGCCCCATC CGCTCGAGGG
951 CTCCAGGAAG GTGGAGGAGG AAGGAAGCCC CGGGGACCCC GACCACGAGG
1001 CCAGCACCCA GGGTCGGACC TGTGGGCCAG AGCATAGCAA GGGTGGGGGC
25 1051 AGGGTGGACG AGGGGCCCCA GCCACGGAGC GTGGAGCCCC AGGATGCGGG
1101 ACCCTTGAG AGGAGCCAGG GGGATGAGGC AGGGGGCCAC GGGGAAGATA
1151 GGCCGGAGCC CTTAAGCCCC AAAGAGAGCA AGAAGAGGAA GCTGGAGCTG
1201 AGCCGGCGGG AGCAGCCGCC CACAGAGCCA GGCCCTCAGA GTGCCTCAGA
1251 GGTGGAGAAG ATCGCTCTGA ATTTGGAGGG GTGTGCCCTC AGCCAGGGCA
30 1301 GCCTCAGGAC GGGGACCCAG GAAGTGGGCG GTCAGGACCC TGGGGAGGCA
1351 GTGCAGCCCT GCCCCAACC CCTGGGAGCC AGGGTGGCCG ACAAGGTGAG
1401 GAAGCGGAGG AAGGTGGATG AGGGTGCTGG GGACAGTGCT GCGGTGGCCA
1451 GTGGTGGTGC CCAGACCTTG GCCCTTGCCG GGTCCCCTGC CCCATCGGGG
1501 CACCCAAGG CTGGACACAG TGAGAACGGG GTTGAGGAGG ACACAGAAGG
35 1551 TCGAACGGGG CCCAAAGAAG GTACCCCTGG GAGCCCATCG GAGACCCCA

```

1601 GCCCCAGCCC AGCAGGACCT GCAGGGGACG AGCCAGCCGA GAGCCCATCG
 1651 GAGACCCAG GCCCCGCCC GGCAGGACCT GCAGGGGACG AGCCAGCCGA
 1701 GAGCCCATCG GAGACCCAG GCCCCAGCCC GGCAGGACCT ACAAGGGATG
 1751 AGCCAGCCGA GAGCCCATCG GAGACCCAG GCCCCGCCC GGCAGGACCT
 5 1801 GCAGGGGACG AGCCAGCCGA GAGCCCATCG GAGACCCAG GCCCCGCCC
 1851 GGCAGGACCT GCAGGGGACG AGCCAGCCGA GAGCCCATCG GAGACCCAG
 1901 GCCCCAGCCC GGCAGGACCT ACAAGGGATG AGCCAGCCAA GGCGGGGGAG
 1951 GCAGCAGAGT TGCAGKACGC AGAGGTGGAG TCTTCTGCCA AGTCTGGGAA
 2001 GCCTTAAGGA AAGGAGTGCC CGTCGGCGTC TTGGTCTCTC TGTCCCTGCT
 10 2051 GCAGGGGCTG GGGCCTCCGG AGCTTGCTGC GGGCTCCCTC CAGGCTCTGC
 2101 TTCGTGACCC GTGACCCATG ACCCACAGTG CTGGCCTCCT GTGGGGCCAC
 2151 TATAGCARSC ACCAGAAGCC GCGAGGCCCT CAGGGAAGCC CAAGGCCTGC
 2201 AGAAGCCTCC TGGCCTGGCT GTGTCTTCCC CACCCAGCTC TCCCCTGCGC
 2251 CCCTGTCTTT GTAAATTGAC CCTTCTGGAG TGGGGGGCGG

Letter "S", "R", or "K" was used in positions where there was a 50-50
 split on the consensus sequences. S = C or G; R = A or G; K = T or G.
 Initiator AUG 34-36

Terminator TAA 2005-2007

20 Open reading frame: 34 (AUGGACGAC...) to 2004 (...GGGAAGCCT)

SEQ ID NO: 5 -- Human Opioid Growth Factor Receptor cDNA, spliced
 version 8

1 TAGAATTCAG CGGCCGCTGA ATTCTAGCCG AGCATGGACG ACCCCGACTG
 51 CCACTCCACC TGGGAGGAGG ACGAGGAGGA TGCAGGAGAC GCGGAGGACG
 101 AGGACTGCGA GGACGGCGAG GCCGCCGGCG CGAGGGACGC GGACGCAGGG
 151 GACGAGGACG AGGAGTCGGA GGAGCCGCGG GCGGCGCGGC CCAGCTCGTT
 201 CCAGTCCAGA ATGACAGGGT CCAGAACTG GCGAGCCACG AGGGACATGT
 251 GTAGGTATCG GCACAACTAT CCGGATCTGG TGGAACGAGA CTGCAATGGG
 301 GACACGCCAA ACCTGAGTTT CTACAGAAAT GAGATCCGCT TCCTGCCCAA
 351 CGGCTGTTTC ATTGAGGACA TTCTTCAGAA CTGGACGGAC AACTATGACC

401 TCCTTGAGGA CAATCACTCC TACATCCAGT GGCTGTTTCC TCTGCGAGAA
 451 CCAGGAGTGA ACTGGCATGC CAAGCCCCTC ACGCTCAGGG AGGTTCGAGGT
 501 GTTTAAAAGC TCCCAGGAGA TCCAGGAGCG GCTTGTCCGG GCCTACGAGC
 551 TCATGCTGGG CTTCTACGGG ATCCGGCTGG AGGACCGAGG CACGGGCACG
 5 601 GTGGGCCGAG CACAGAACTA CCAGAAGCGC TTCCAGAACC TGAAGTGGCG
 651 CAGCCACAAC AACCTCCGCA TCACACGCAT CCTCAAGTCG CCGTGTGAGC
 701 TGAGCCTCGA GCACTTCCAG GCGCCACTGG TCCGCTTCTT CCTGGAGGAG
 751 ACGCTGGTGC GGCGGGAGCT GCCGGGGGTG CGGCAGAGTG CCCTGGACTA
 801 CTTTCATGTTT GCCGTGCGCT GCCGACACCA GCGCCGCCAG CTGGTGCCT
 10 851 TCGCCTGGGA GCACTTCCGG CCCCCTGCA AGTTCGTCTG GGGGCCCCAA
 901 GACAAGCTGC GGAGGTTCAA GCCCAGCTCT CTGCCGCATC CGCTCGAGGG
 951 CTCCAGGAAG GTGGAGGAGG AAGGAAGCCC CGGGGACCCC GACCACGAGG
 1001 CCAGCACCCA GGGTCGGACC TGTGAGCCAG AGCATAGCAA GGGTGGGGGC
 1051 AGGGTGGACG AGGGGCCCCA GCCACGGAGC GTGGAGCCCC AGGATGCGGG
 15 1101 ACCCCTGGAG AGGAGCCAGG GGGATGAGGC AGGGGGCCAC GGGGAAGATA
 1151 GGCCGGAGCC CTTAAGCCCC AAAGAGAGCA AGAAGAGGAA GCTGGAGCTG
 1201 AGCCGGCGGG AGCAGCCGCC CACAGGGCCA GGCCCTCAGA GTGCCTCAGA
 1251 GGTGGAGAAG ATCGCTCTGA ATTTGGAGGG GTGTGCCCTC AGCCAGGGCA
 1301 GCCTCAGGAC GGGGACCCAG GAAGTGGGCG GTCAGGACCC TGGGGAGGCA
 20 1351 GTGCAGCCCT GCCGCCAACC CCTGGGAGCC AGGGTGGCCG ACAAGGTGAG
 1401 GAAGCGGAGG AAGGTGGATG AGGGTACTGG GGACAGTGCT GCGGTGGCCA
 1451 GTGGTGGTGC CCAGACCTTG GCCCTTGCCG GGTCCCCTGC CCCATCGGGG
 1501 CACCCAAGG CTGGACACAG TGAGAACGGG GTTGAGGAGG ACACAGAAGG
 1551 TCGAACGGGG CCCAAAGAAG GTACCCCTGG GAGCCCATCG GAGACCCAG
 25 1601 GCCCCAGCCC AGCAGGACCT GCAGGGGACG AGCCAGCCAA GACCCCATCG
 1651 GAGACCCAG GCCCCAGCCC GGCAGGACCT ACAAGGGATG AGCCAGCCGA
 1701 GAGCCCATCG GAGACCCAG GCCCCGCCC GGCAGGACCT GCAGGGGACG
 1751 AGCCAGCCGA GAGCCCATCG GAGACCCAG GCCCCGCCC GGCAGGACCT
 1801 GCAGGGGACG AGCCAGCCAA GATCCCATCG GAGACCCAG GCCCCAGCCC
 30 1851 GGCAGGACCT ACAAGGGATG AGCCAGCCGA GAGCCCATCG GAGACCCAG
 1901 GCCCCGCCC GGCAGGACCT GCAGGGGACG AGCCAGCCGA GAGCCCATCG
 1951 GAGACCCAG GCCCCGCCC GGCAGGACCT GCAGGGGACG AGCCAGCCGA

2001 GAGCCCATCG GAGACCCAG GCCCAGCCC GGCAGGACCT ACAAGGGATG
 2051 AGCCAGCCAA GGCGGGGGAG GCAGCAGAGT TGCAGGACGC AGAGGTGGAG
 2101 TCTTCTGCCA AGTCTGGGAA GCCTTAAGGA AAGGAGTGCC CGTCGGCGTC
 2151 TTGGTCCTCC TGTCCCTGCT GCAGGGGCTG GGGCCTCCGG AGCTGCTGCG
 5 2201 GGCTCCCCTC AGGCTCTGCT TCGTGACCCG TGACCCATGA CCCACAGTGC
 2251 TGGCCTCCTG TGGGGCCACT ATAGCAGCCA CCAGAAGCCG CGAGGGCCCTC
 2301 AGGGAAGCCC AAGGCCTGCA GAAGCCTCCT GGCCTGGCTG TGTCTTCCCC
 2351 ACCCAGCTCT CCCCTGCGCC CCTGTCTTTG TAAATTGACC CTTCTGGAGT
 2401 GGGGGGCG

SEQ ID NO: 6 -- Human Opioid Growth Factor Receptor protein, from
 spliced cDNA version 8

15 MDDPDCDSTWEEDEEDAEDAEDDCEDGEAAGARDADAGDEDEESEEPRAARPSSFQSRM 60
 TGSRNWRATRDMCRYRHNPDLVERDCNGDTPNLSFYRNEIRFLPNGCFIEDILQNWTDN 120
 YDLLEDNHSYIQWLFPLREPGVNWHAHAKPLTLREVEVFKSSQEIQLVRLVAYELMLGFYGI 180
 RLEDRTGTGVGRAQNYQKRFQNLNWRSHNNLRITRILKSPCELSLEHFQAPLVRFFLEET 240
 LVRRELPGVRQSALDYFMFAVRCRHQRRQLVHFAWEHFRPRCKFVWGPQDKLRRFKPSSL 300
 20 PHPLEGSRKVEEEGSPGDPDHEASTQGRTEPEHSGGGRVDEGPQPRSVEPQDAGPLER 360
 SQGDEAGGHGEDRPEPLSPKESKKRKLELSRREQPPTGPGPQSASEVEKIALNLEGCALS 420
 QGSLRTGTQEVGGQDPGEAVQPCRQPLGARVADKVRKRRKVDEGTGDSAASVSGGAQTLA 480
 LAGSPAPSGHPKAGHSENGVEEDTEGRTGPKETPGSPSETPGPSPAGPAGDEPAKTPSE 540
 TPGPSPAGPTRDEPAESPSETPGPRPAGPAGDEPAESPSETPGPRPAGPAGDEPAKIPSE 600
 25 TPGPSPAGPTRDEPAESPSETPGPRPAGPAGDEPAESPSETPGPRPAGPAGDEPAESPSE 660
 TPGPSPAGPTRDEPAKAGEAAELQDAEVESAKSGKP 697

SEQ ID NO: 7 -- Human OGFr cDNA, spliced version 1

1 TAGAATTCAG CGGCCGCTGA ATTCTAGCCG AGCATGGACG ACCCCGACTG
 51 CGACTCCACC TGGGAGGAGG ACGAGGAGGA TGCGGAGGAC GCGGAGGACG

101 AGGACTGCGA GGACGGCGAG GCCGCCGGCG CGAGGGACGC GGACGCAGGG
 151 GACGAGGACG AGGAGTCGGA GGAGCCGCGG GCGGCGCGGC CCAGCTCGTT
 201 CCAGTCCAGA ATGACAGGGT CCAGAAACTG GCGAGCCACG AGGGACATGT
 251 GTAGGTATCG GCACAACTAT CCGGATCTGG TGAACGAGA CTGCAATGGG
 5 301 GACACGCCAA ACCTGAGTTT CTACAGAAAT GAGATCCGCT TCCTGCCCCA
 351 CGGCTGTTTC ATTGAGGACA TTCTTCAGAA CTGGACGGAC AACTATGACC
 401 TCCTTGAGGA CAATCACTCC TACATCCAGT GGCTGTTTCC TCTGCGAGAA
 451 CCAGGAGTGA ACTGGCATGC CAAGCCCCTC ACGCTCAGGG AGGTGAGGT
 501 GTTTAAAAGC TCCCAGGAGA TCCAGGAGCG GCTTGTCGGG GCCTACGAGC
 10 551 TCATGCTGGG CTTCTACGGG ATCCGGCTGG AGGACCGAGG CACGGGCACG
 601 GTGGGCCGAG CACAGAACTA CCAGAAGCGC TTCCAGAACC TGAAGTGGCG
 651 CAGCCACAAC AACCTCCGCA TCACACGCAT CCTCAAGTCG CCGTGTGAGC
 701 TGAGCCTCGA GCACTTCCAG GCGCCACTGG TCCGCTTCTT CCTGGAGGAG
 751 ACGCTGGTGC GCGGGGAGCT GCCGGGGGTG CGGCAGAGTG CCCTGGACTA
 15 801 CTTCATGTTC GCCGTGCGCT GCCGACACCA GCGCCGCCAG CTGGTGCACT
 851 TCGCCTGGGA GCACTTCCGG CCCCCTGCA AGTTCGTCTG GGGGCCCCAA
 901 GACAAGCTGC GGAGGTTCAA GCCCAGCTCT CTGCCGCATC CGCTCGAGGG
 951 CTCCAGGAAG GTGGAGGAGG AAGGAAGCCC CGGGGACCCC GACCACGAGG
 1001 CCAGCACCCA GGGTCGGACC TGTGGGCCAG AGCATAGCAA GGGTGGGGGC
 20 1051 AGGGTGGACG AGGGGCCCCA GCCACGAGC GTGGAGCCCC AGGATGCGGG
 1101 ACCCCTGGAG AGGAGCCAGG GGGATGAGGC AGGGGGCCAC GGGGAAGATA
 1151 GGCCGGAGCC CTTAAGCCCC AAAGAGAGCA AGAAGAGGAA GCTGGAGCTG
 1201 AGCCGGCGGG AGCAGCCGCC CACAGAGCCA GGCCCTCAGA GTGCCTCAGA
 1251 GGTGGAGAAAG ATCGCTCTGA ATTTGGAGGG GTGTGCCCTC AGCCAGGGCA
 25 1301 GCCTCAGGAC GGGGACCCAG GAAGTGGGCG GTCAGGACCC TGGGGAGGCC
 1351 TCCTGTCCCT GCTGCAGGGG CTGGGGCCTC CGGAGCTGCT GCGGGCTCCC
 1401 CTCAGGCTCT GCTTCGTGAC CCGTGACCCA TGACCCACAG TGCTGGCCTC
 1451 CTGTGGGGCC ACTATAGCAG CCACCAGAAG CCGCGAGGCC CTCAGGGAAG
 1501 CCAAGGCCT GCAGGAGCCT CCTGGCCTGG CTGTGTCTTC CCCACCCAGC
 30 1551 TCTCCCCTGC GCCCCTGTCT TTGTAAATTG ACCCTTCTGG AGTGGGGGGC
 1601 G

SEQ ID NO: 8 -- Human Opioid Growth Factor Receptor protein, from
spliced cDNA version 1

```

5  MDDPDCDSTWEEDEEDAEDAEDCEDCEAAGARDADAGDEDEESEEPRAARPSSFQSRM      60
   TGSRNWRATRDMCRYRHNYPDLVERDCNGDTPNLSFYRNEIRFLPNGCFIEDILQNWTDN    120
   YDLLEDNHSYIQWLFPLREPGVNWHA KPLTLREVEVFKSSQEIQERLVRAYELMLGFYGI    180
   RLEDRGTTGVGRAQNYQKRFQNLNWRSHNNLRITRILKSPCELSLEHFQAPLVRFFLEET    240
   LVRRELPGVRQSALDYFMFAVRCRHQRRLVHFAWEHFRPRCKFVWGPQDKLRRFKPSSL    300
10  PHPLEGSRKVEEEGSPGDPDHEASTQGRTCGPEHSKGGGRVDEGPQPRSVEPQDAGPLER    360
   SQGDEAGGHGEDRPEPLSPKESKKRKLELSRREQPPTEPGPQSASEVEKIALNLEGCALS    420
   QGSLRTGTQEVGGQDPGEASCPCCRGWGLRSCCGLPSGSAS                        461

```

15 SEQ ID NO: 9 -- Human OGFr cDNA, spliced version 4

```

      1  TAGAATTCAG CGGCCGCTGA ATTCTAGCCG AGCATGGACG ACCCCGACTG
      51  CGACTCCACC TGGGAGGAGG ACGAGGAGGA TGCGGAGGAC GCGGAGGACG
     101  AGGACTGCGA GGACGGCGAG GCCGCCGGCG CGAGGGACGC GGACGCAGGG
    20  151  GACGAGGACG AGGAGTCGGA GGAGCCGCGG GCGGCGCGGC CCAGCTCGTT
      201  CCAGTCCAGA ATGACAGGGT CCAGAACTG GCGAGCCACG AGGGACATGT
      251  GTAGGTATCG GCACAACTAT CCGGATCTGG TGGAACGAGA CTGCAATGGG
      301  GACACGCCAA ACCTGAGTTT CTACAGAAAT GAGATCCGCT TCCTGCCCAA
      351  CGGCTGTTTC ATTGAGGACA TTCTTCAGAA CTGGACGGAC AACTATGACC
    25  401  TCCTTGAGGA CAATCACTCC TACATCCAGT GGCTGTTTCC TCTGCGAGAA
      451  CCAGGAGTGA ACTGGCATGC CAAGCCCCTC ACGCTCAGGG AGGTCGAGGT
      501  GTTTAAAAGC TCCAGGAGA TCCAGGAGCG GCTTGTCCGG GCCTACGAGC
      551  TCATGCTGGG CTTCTACGGG ATCCGGCTGG AGGACCGAGG CACGGGCACG
      601  GTGGGCCGAG CACAGAACTA CCAGAAGCGC TTCCAGAACC TGAAGTGGCG
    30  651  CAGCCACAAC AACCTCCGCA TCACACGCAT CCTCAAGTCG CCGTGTGAGC
      701  TGAGCCTCGA GCACTTCCAG GCGCCACTGG TCCGCTTCTT CCTGGAGGAG
      751  ACGCTGGTGC GCGGGGAGCT GCCGGGGGTG CGGCAGAGTG CCCTGGACTA

```

	801	CTTCATGTTT	GCCGTGCGCT	GCCGACACCA	GCGCCGCCAG	CTGGTGCACT
	851	TCGCCTGGGA	GCACTTCCGG	CCCCGCTGCA	AGTTCGTCTG	GGGGCCCCAA
	901	GACAAGCTGC	GGAGGTTCAA	GCCCAGCTCT	CTGCCGCATC	CGCTCGAGGG
	951	CTCCAGGAAG	GTGGAGGAGG	AAGGAAGCCC	CGGGGACCCC	GACCACGAGG
5	1001	CCAGCACCCA	GGGTCTGGACC	TGTGGGCCAG	AGCATAGCAA	GGGTGGGGGC
	1051	AGGGTGGACG	AGGGGCCCCA	GCCACGGAGC	GTGGAGCCCC	AGGATGCGGG
	1101	ACCCCTGGAG	AGGAGCCAGG	GGGATGAGGC	AGGGGGCCAC	GGGGAAGATA
	1151	GGCCGGAGCC	CTTAAGCCCC	AAAGAGAGCA	AGAAGAGGAA	GCTGGAGCTG
	1201	AGCCGGCGGG	AGCAGCCGCC	CACAGAGCCA	GGCCCTCAGA	GTGCCTCAGA
10	1251	GGTGGAGAAG	ATCGCTCTGA	ATTTGGAGGG	GTGTGCCCTC	AGCCAGGGCA
	1301	GCCTCAGGAC	GGGGACCCAG	GAAGTGGGCG	GTCAGGACCC	TGGGGAGGCA
	1351	GTGCAGCCCT	GCCGCCAACC	CCTGGGAGCC	AGGGTGGCCG	ACAAGGTGAG
	1401	GAAGCGGAGG	AAGGTGGATG	AGGGTGCTGG	GGACAGTGCT	GCGGTGGCCA
	1451	GTGGTGGTGC	CCAGACCTTG	GCCCTTGCCG	GGTCCCCTGC	CCCATCGGGG
15	1501	CACCCCAAGG	CTGGACACAG	TGAGAACGGG	GTTGAGGAGG	ACACAGAAGG
	1551	TCGAACGGGG	CCCAAAGAAG	GTACCCCTGG	GAGCCCATCG	GAGACCCAG
	1601	GCCCCAGCCC	AGCAGGACCT	GCAGGGGACG	AGCCAGCCGA	GAGCCCATCG
	1651	GAGACCCAG	GCCCCCGCCC	AGCAGGACCT	GCAGGGGACG	AGCCAGCCGA
	1701	GAGCCCATCG	GAGACCCAG	GCCTCCGCCC	GGCAGGACCT	GCAGGGGACG
20	1751	AGCCAGCCGA	GACCCCATCG	GAGACCCAG	GCCCCAGCCC	GGCAGGACCT
	1801	ACAAGGGATG	AGCCAGCCGA	GAGCCCATCG	GAGACCCAG	GCCCCCGCCC
	1851	GGCAGGACCT	GCAGGGGACG	AGCCAGCCGA	GAGCCCATCG	GAGACCCAG
	1901	GCCCCCGCCC	GGCAGGACCT	GCAGGGGACG	AACCAGCCGA	GAGCCCATCG
	1951	GAGACCCAG	GCCCCAGCCC	GGCAGGACCT	ACAAGGGATG	AGCCAGCCAA
25	2001	GGCGGGGGAG	GCAGCAGAGT	TGCAGGACGC	AGAGGTGGAG	TCTTCTGCCA
	2051	AGTCTGGGAA	GCCTTAAGGA	AAGGAGTGCC	CGTCGGCGTC	TTGGTCTCTC
	2101	TGTCCCTGCT	GCAGGGGCTG	GGGCCTCCGG	AGCTGCTGCG	GACTCCCCTC
	2151	AGGCTCTGCT	TCGTGACCCG	TGACCCATGA	CCCACAGTGC	TGGCCTCCTG
	2201	TGGGGCCACT	ATAGCAGCCA	CCAGAAGCCG	CGAGGCCCTC	AGGGAAGCCC
30	2251	AAGGCCTGCA	GAAGCCTCCT	GGCCTGGCTG	TGTCTTCCCC	ACCCAGCTCT
	2301	CCCCTGCGCC	CCTGTCTTTG	TAAATTGACC	CTTCTGGAGT	GGGGGGCG

SEQ ID NO: 10 -- Human OGFr, from spliced cDNA version 4

5 MDDPDCDSTWEEDEEDAEDAEDCEDGGEAAGARDADAGDEDEESEEPRARPSSSFQSRM 60
 TGSRNWRATRDMCRYRHNPDLVERDCNGDTPNLSFYRNEIRFLPNGCFIEDILQNWTDN 120
 YDLLEDNHSYIQWLFPLREPGVNVHAKPLTLREVEVFKSSQEIQERLVRAYELMLGFYGI 180
 RLEDRTGTGVGRAQNYQKRFQNLNWRSHNNLRITRILKSPCELSLEHFQAPLVRFFLEET 240
 LVRRELPGVRQSAIDYFMFAVRCRHQRRQLVHFAWEHFRPRCKFVWGPQDKLRRFKPSSL 300
 PHPLEGSRKVEEEGSPGDPDHEASTQGRTCGPEHSKGGGRVDEGPQPRSVEPQDAGPLER 360
 SQGDEAGGHGEDRPEPLSPKESKKRKLELSRREQPPTEPGPQSASEVEKIALNLEGCALS 420
 10 QGSLRTGTQEVGGQDPGEAVQPCRQPLGARVADKVRKRRKVDEGAGDSAASGGAQTLA 480
 LAGSPAPSGHPKAGHSENGVEEDTEGRTGPKEGTPGSPSETPGPSPAGPAGDEPAESPSE 540
 TPGPRPAGPAGDEPAESPSETPGLRPAGPAGDEPAETPSETPGPSPAGPTRDEPAESPSE 600
 TPGPRPAGPAGDEPAESPSETPGPRPAGPAGDEPAESPSETPGPSPAGPTRDEPAKAGEA 660
 AELQDAEVESSAKSGKP

15

SEQ ID NO: 11 -- Human OGFr cDNA, spliced version 7

1 TAGAATTCAG CGGCCGCTGA ATTCTAGCCG AGCATGGACG ACCCCGACTG
 20 51 CGACTCCACC TGGGAGGAGG ACGAGGAGGA TGCGGAGGAC GCGGAGGACG
 101 AGGACTGCGA GGACGGCGAG GCCGCCGGCG CGAGGGACGC GGACGCAGGG
 151 GACGAGGACG AGGAGTCGGA GGAGCCGCGG GCGGCGCGGC CCAGCTCGTT
 201 CCAGTCCAGA ATGACAGGGT CCAGAACTG GCGAGCCACG AGGGACATGT
 251 GTAGGTATCG GCACAACTAT CCGGATCTGG TGGAACGAGA CTGCAATGGG
 25 301 GACACGCCAA ACCTGAGTTT CTACAGAAAT GAGATCCGCT TCCTGCCCAA
 351 CGGCTGTTTC ATTGAGGACA TTCTTCAGAA CTGGACGGAC AACTATGACC
 401 TCCTTGAGGA CAATCACTCC TACATCCAGT GGCTGTTTCC TCTGCGAGAA
 451 CCAGGAGTGA ACTGGCATGC CAAGCCCCTC ACGCTCAGGG AGGTCGAGGT
 501 GTTTAAAAGC TCCCAGGAGA TCCAGGAGCG GCTTGTCCGG GCCTACGAGC
 30 551 TCATGCTGGG CTTCTACGGG ATCCGGCTGG AGGACCGAGG CACGGGCACG
 601 GTGGGCCGAG CACAGAACTA CCAGAAGCGC TTCCAGAACC TGAAGTGGCG
 651 CAGCCACAAC AACCTCCGCA TCACACGCAT CCTCAAGTCG CCGTGTGAGC

5
701 TGAGCCTCGA GCACTTCCAG GCGCCACTGG TCCGCTTCTT CCTGGAGGAG
751 ACGCTGGTGC GGCGGGAGCT GCCGGGGGTG CGGCAGAGTG CCCTGGACTA
801 CTTTCATGTTT GCCGTGCGCT GCCGACACCA GCGCCGCCAG CTGGTGCAC
851 TCGCCTGGGA GCACTTCCGG CCCCCTGCA AGTTCGTCTG GGGGCCCCAA
901 GACAAGCTGC GGAGGTTCAA GCCCAGCTCT CTGCCCCATC CGCTCGAGGG
951 CTCCAGGAAG GTGGAGGAGG AAGGAAGCCC CGGGGACCCC GACCACGAGG
1001 CCAGCACCCA GGGTCGGACC TGTGGGCCAG AGCATAGCAA GGGTGGGGGC
1051 AGGGTGGACG AGGGGCCCCA GCCACGGAGC GTGGAGCCCC AGGATGCGGG
1101 ACCCCTGGAG AGGAGCCAGG GGGATGAGGC AGGGGGCCAC GGGGAAGATA
10
1151 GGCCGGAGCC CTTAAGCCCC AAAGAGAGCA AGAAGAGGAA GCTGGAGCTG
1201 AGCCGGCGGG AGCAGCCGCC CACAGAGCCA GGCCCTCAGA GTGCCTCAGA
1251 GGTGGAGAAG ATCGCTCTGA ATTTGGAGGG GTGTGCCCTC AGCCAGGGCA
1301 GCCTCAGGAC GGGGACCCAG GAAGTGGGCG GTCAGGACCC TGGGGAGGCA
1351 GTGCAGCCCT GCCGCCAACC CCTGGGAGCC AGGGTGGCCG ACAAGGTGAG
15
1401 GAAGCGGAGG AAGGTGGATG AGGGTGCTGG GGACAGTGCT GCGGTGGCCA
1451 GTGGTGGTGC CCAGACCTTG GCCCTTGCCG GGTCCCCTGC CCCATCGGGG
1501 CACCCCAAGG CTGGACACAG TGAGAACGGG GTTGAGGAGG ACACAGAAGG
1551 TCGAACGGGG CCCAAAGAAG GTACCCCTGG GAGCCCATCG GAGACCCAG
1601 GCCCCAGCCC AGCAGGACCT GCAGGGGACG AGCCAGCCGA GAGCCCATCG
20
1651 GAGACCCAG GCCCCGCCC GGCAGGACCT GCAGGGGACG AGCCAGCCGA
1701 GAGCCCATCG GAGACCCAG GCCCCAGCCC GGCAGGACCT ACAAGGGATG
1751 AGCCAGCCGA GAGCCCATCG GAGACCCAG GCCCCGCCC GGCAGGACCT
1801 GCAGGGGACG AGCCAGCCGA GAGCCCATCG GAGACCCAG GCCCCGCCC
1851 GGCAGGACCT GCAGGGGACG AGCCAGCCGA GAGCCCATCG GAGACCCAG
25
1901 GCCCCAGCCC GGCAGGACCT ACAAGGGATG AGCCAGCCAA GGCGGGGGAG
1951 GCAGCAGAGT TGCAGGACGC AGAGGTGGAG TCTTCTGCCA AGTCTGGGAA
2001 GCCTTAAGGA AAGGAGTGCC CGTCGGCGTC TTGGTCCTCC TGTCCCTGCT
2051 GCAGGGGCTG GGGCCTCCGG AGCTGCTGCG GGCTCCCCTC AGGCTCTGCT
2101 TCGTGACCCG TGACCCATGA CCCACAGTGC TGGCCTCCTG TGGGGCCACT
30
2151 ATAGCAGCCA CCAGAAGCCG CGAGGCCCTC AGGGAAGCCC AAGGCCTGCA
2201 GAAGCCTCCT GGCCTGGCTG TGTCTTCCCC ACCCAGCTCT CCCCTGCGCC
2251 CCTGTCTTTG TAAATTGACC CTTCTGGAGT GGGGGGCGG

SEQ ID NO: 12, Human OGFr, from spliced cDNA version 7

MDDPDCDSTWEEDEEDAEDAEDCEDCEGAAAGARDADAGDEDEESEEPRAARPSSFQSRM 60
 5 TGSRNWRATRDMCRYRHNPDLVERDCNGDTPNLSFYRNEIRFLPNGCFIEDILQNWDN 120
 YDLLEDNHSYIQWLFPLREPGVNWHA KPLTLREVEVFKSSQEIQERLVRAYELMLGFYGI 180
 RLEDRGTTGTVGRAQNYQKRFQNLNWRSHNNLRITRILKSPCELSLEHFQAPLVRFFLEET 240
 LVRRELPGVRQSALDYFMFAVRCRHQRRQLVHFAWEHFRPRCKFVWGPQDKLRRFKPSSL 300
 PHPLEGSRKVEEEGSPGDPDHEASTQGRTCGPEHSKGGGRVDEGPQPRSVEPQDAGPLER 360
 10 SQGDEAGGHGEDRPEPLSPKESKKRKLELSRREQPPTEPGPQSASEVEKIALNLEGCALS 420
 QGSLRTGTQEVGGQDPGEAVQPCRQPLGARVADKVRKRRKVDEGAGDSA AVASGGAQTLA 480
 LAGSPAPSGHPKAGHSENGVEEDTEGRTGPKEGTPGSPSETPGPSPAGPAGDEPAESPSE 540
 TPGPRPAGPAGDEPAESPSETPGPSPAGPTRDEPAESPSETPGPRPAGPAGDEPAESPSE 600
 TPGPRPAGPAGDEPAESPSETPGPSPAGPTRDEPAKAGEAAELQDAEVESAKSGKP 657

15

SEQ ID NO: 13 -- Human OGFr cDNA, spliced version 127

1 TAGAATTCAG CGGCCGCTGA ATTCTAGCCG AGCATGGACG ACCCCGACTG
 20 51 CGACTCCACC TGGGAGGAGG ACGAGGAGGA TGCGGAGGAC GCGGAGGACG
 101 AGGACTGCGA GGACGGCGAG GCCGCCGGCG CGAGGGACGC GGACGCAGGG
 151 GACGAGGACG AGGAGTCGGA GGAGCCGCGG GCGGCGCGGC CCAGCTCGTT
 201 CCAGTCCAGA ATGACAGGGT CCAGAACTG GCGAGCCACG AGGGACATGT
 251 GTAGGTATCG GCACAACTAT CCGGATCTGG TGGAACGAGA CTGCAATGGG
 25 301 GACACGCCAA ACCTGAGTTT CTACAGAAAT GAGATCCGCT TCCTGCCCAA
 351 CGGCTGTTTC ATTGAGGACA TTCTTCAGAA CTGGACGGAC AACTATGACC
 401 TCCTTGAGGA CAATCACTCC TACATCCAGT GGCTGTTTCC TCTGCGAGAA
 451 CCAGGAGTGA ACTGGCATGC CAAGCCCCTC ACGCTCAGGG AGGTCGAGGT
 501 GTTTAAAAGC TCCAGGAGA TCCAGGAGCG GCTTGTCCGG GCCTACGAGC
 30 551 TCATGCTGGG CTTCTACGGG ATCCGGCTGG AGGACCGAGG CACGGGCACG
 601 GTGGGCCGAG CACAGAACTA CCAGAAGCGC TTCCAGAACC TGAAGTGGCG
 651 CAGCCACAAC AACCTCCGCA TCACACGCAT CCTCAAGTCG CCGTGTGAGC

701 TGAGCCTCGA GCACTTCCAG GCGCCACTGG TCCGCTTCTT CCTGGAGGAG
 751 ACGCTGGTGC GGCGGGAGCT GCCGGGGGTG CGGCAGAGTG CCCTGGACTA
 801 CTTTCATGTTT GCCGTGCGCT GCCGACACCA GCGCCGCCAG CTGGTGCACG
 851 TCGCCTGGGA GCACTTCCGG CCCCCTGCA AGTTCGTCTG GGGGCCCCAA
 5 901 GACAAGCTGC GGAGGTTCAA GCCCAGCTCT CTGCCGCATC CGCTCGAGGG
 951 CTCCAGGAAG GTGGAGGAGG AAGGACCTGC AGGGGACGAG CCAGCCGAGA
 1001 GCCCATCGGA GACCCCAGGC CCCAGCCCGG CAGGACCTAC AAGGGATGAG
 1051 CCAGCCAAGG CGGGGGAGGC AGAAGCCTGC TGCCTGGCTG TGTCTTCCCA
 1101 CCCAGCTCTC CCCTGCGCCC CTGTCTTTGT TAATCGACCC TTCTGGAGCG
 10 1151 GGGGGCGGCG GGCAGGGCTT GCCTTTCTTA GTCTGATGCC AAGCAAGGCC
 1201 TTTTCTGAAT AAATTCATTT GACTTTCGAA AA

SEQ ID NO: 14 -- Human OGF α , from spliced cDNA version 127

15 MDDPDCDSTWEEDEEDAEDAEDCEDGEEAAGARDADAGDEDEESEEPRARPSSSFQSRM 60
 TGSRNWRATRDRCRYRHNPDLVERDCNGDTPNLSFYRNEIRFLPNGCFIEDILQNWTDN 120
 YDLLEDNHSYIQWLFPLREPGVNWHAHPLTLREVEVFKSSQEIQLRVAYELMLGFYGI 180
 RLEDRTGTGVGRAQNYQKRFQNLNWRSHNNLRITRILKSPCELSLEHFQAPLVRFFLEET 240
 20 LVRRELPGVRQSALDYFMFAVRCRHQRRQLVHFAWEHFRPRCKFVWGPQDKLRRFKPSSL 300
 PHPLEGSRKVEEEGPAGDEPAESPSETPGPSPAGPTRDEPAKAGEAEACCLAVSSHPALP 360
 CAPVFVNRPFWSGGRRAGLAFSLMPSKAFSE 392

WE CLAIM:

1. An isolated nucleic acid molecule comprising any of SEQ
5 ID NOS: 1, 4-5, 7, 9, 11 or 13, or a fragment thereof.

2. An isolated nucleic acid molecule substantially
homologous to any of SEQ ID NOS: 1, 4-5, 7, 9, 11 or 13.

10 3. An isolated nucleic acid molecule, the complement
sequence of which hybridize under stringent conditions to any of
SEQ ID NOS: 1, 4-5, 7, 9, 11 and 13.

15 4. An isolated nucleic acid molecule comprising an antisense
sequence of any of SEQ ID NOS: 1, 4-5, 7, 9, 11 and 13.

5. An expression vector comprising any of the isolated
nucleic acid molecules of claims 1-4.

20 6. A cell, transformed with the expression vector of claim
5.

25 7. A method of producing an OGFr protein or a fragment
thereof, comprising transforming a host cell with an expression
vector, wherein said expression vector encodes said OGFr protein
or a fragment thereof, expressing said OGFr protein or said
fragment thereof in the cell and recovering said protein or said
fragment thereof.

30 8. The method of claim 7, wherein said OGFr is encoded by
any of SEQ ID NOS: 1, 4-5, 7, 9, 11 or 13.

9. An isolated protein consisting any of SEQ ID NOs: 2, 6, 8, 10, 12 and 14.

10. The isolated protein of claim 9, wherein said protein is made recombinantly.

11. A functional derivative of any of SEQ ID NO: 2, 6, 8, 10, 12 and 14.

12. An antibody directed against an OGE_r protein consisting of any of SEQ ID NOs: 2, 6, 8, 10, 12 and 14.

13. The antibody of claim 10, wherein said antibody is a monoclonal antibody.

14. A pharmaceutical composition comprising the isolated nucleic acid molecule of claim 1 and a pharmaceutically acceptable carrier.

15. A pharmaceutical composition comprising the isolated nucleic acid molecule of claim 4 and a pharmaceutically acceptable carrier.

16. A pharmaceutical composition comprising the expression vector of claim 5 and a pharmaceutically acceptable carrier.

17. A pharmaceutical composition comprising the cell of claim 6 and a pharmaceutically acceptable carrier.

18. A pharmaceutical composition comprising the isolated protein of claim 9 and a pharmaceutically acceptable carrier.

19. A pharmaceutical composition comprising the functional derivative of claim 11 and a pharmaceutically acceptable carrier.

20. A pharmaceutical composition comprising the antibody of
5 claim 12 and a pharmaceutically acceptable carrier.

21. A method of detecting the expression of an OGF receptor in a tissue of a subject, comprising contacting a sample of said tissue with a nucleic acid sequence encoding said OGFr or a
10 portion thereof and determining the level of the mRNA encoding said OGFr.

22. A method of detecting the level of an OGF receptor in a tissue of a subject, comprising contacting a sample of said
15 tissue with an antibody specific for said OGFr, detecting and quantitating the complexes formed between said OGFr and said antibody.

23. A method of inhibiting growth of cells *in vitro*
20 comprising introducing to said cells an effective amount of nucleic acid molecules coding for an OGFr or a functional derivative thereof.

24. A method of promoting growth of cells *in vitro*
25 comprising introducing to said cells an effective amount of an OGFr antisense molecule.

25. A method of promoting growth of cells *in vitro*
comprising introducing to said cells an effective amount of an
30 antibody directed against an OGFr expressed in such cells.

26. A method of treating cancer in a patient comprising enhancing the function of the OGF ligand-receptor system in the cancerous cells of said patient.

5 27. A method of treating cancer in a patient comprising administering to said patient, an effective amount of a nucleic acid molecule coding for an OGFr or a functional derivative thereof.

10 28. The method of claim 27, wherein said cancer is selected from the group consisting of a cancer of neural tissues, prostate cancer, breast cancer, head and neck cancer, and gastrointestinal cancer.

15 29. The method of claim 28, wherein said gastrointestinal cancer is selected from the group consisting of a pharyngeal, esophageal, stomach, small and large intestine, liver, rectal, colon, pancreatic, biliary tract cancer.

20 30. The method of claim 27, wherein said cancer is characterized by a deficiency of OGF receptors.

31. The method of claim 27, further comprising administering OGF to said subject.

25 32. A method of treating a subject with a cancer characterized by a deficiency of OGF receptors, comprising determining the deficiency of OGF receptors on the cancerous cells in said subject, and administering to the subject an
30 effective amount of a nucleic acid molecule coding for an OGFr or a functional derivative thereof.

33. The method of claim 33, further comprising
adminisitering OGF to said subject.

34. A method of promoting growth of cells in a subject in
5 need thereof comprising interfering with the function of the OGF
ligand-receptor system in said subject.

35. The method of claim 34, wherein said subject suffers a
tissue wound.

10

36. The method of claim 34, comprising administering to
said subject, an effective amount of an OGFr antisense molecule.

37. The method of claim 34, comprising administering to
15 said subject, an effective amount of an antibody against an OGFr.

ABSTRACT

5 This invention relates to novel nucleic acid molecules
coding for opioid growth factor receptors. In particular, the
present invention provides isolated nucleic acid molecules coding
for human and rat OGF receptors. Antisense molecules, expression
vectors and host cells, isolated proteins encoded by such nucleic
10 acid molecules, antibodies directed against such proteins, as
well as pharmaceutical compositions derived therefrom are also
included. The invention further provides methods of modulating
cell growth by using the isolated nucleic acid molecules, the
antisense molecules and the antibodies directed against the
15 encoded proteins.